CERTIFICATION OF APPROVAL

Implication of Tidal Wave and Heavy Rainfall Towards Drainage In Estuary

By

Khalidah Binti Kamaluddin

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Approved by,

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(HUSNA BINTI TAKAIJUDIN)

UNIVERSITI TEKNOLOGI PETRONAS

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contains herein have not been undertaken or done by unspecified sources or persons.

(KHALIDAH BINTI KAMALUDDIN)

ABSTRACT

Estuary is a semi-enclosed coastal body of water which has free connection with the sea, thus is strongly affected by the tidal action. Also in these areas, the level of the receiving water body is directly or indirectly affected by tidal or wave effects, including different rainfall conditions in varying intensity and duration. Estuaries as a low-lying area will be facing a direct effect from the conditions of huge tidal and heavy rainfall occurrences. This paper investigates the behaviour of the drainage in estuaries with occurrences of tidal wave and heavy rainfall. Study of the tidal affect and rainfall towards drainage system is carried out in Sungai Dinding Kiri area in Sitiawan, Perak and which the drainage of study area is located in Kampung Baru, Sitiawan which is very near to the estuary. The 100 years ARI rainfall is analysed, as stated in MASMA. Collections of data, consisting of water level and flow of water were conducted for four consecutive months. HEC-RAS Software was then used to simulate and analyse the data. To determine the effective water discharge of channel in the study area, Min and Mean Section Method were used. The peak water discharge from Sungai Dinding is $851.66 m^3/s$.

ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious, the Most Merciful. Praise to Him the Almighty that in his will and given strength, I managed to complete this Final Year Project for the Petroleum Engineering Department, of Universiti Teknologi PETRONAS.

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CHAPTER 1

INTRODUCTION

1.0 Background

In the twentieth century, not much was done in respect of agricultural drainage except for the cultivation of paddy. Land drainage for agricultural crops other than paddy was carried out independently by estate owners and small holders to serve their limited purpose and, consequently, there was little or no co-ordination effort. These early reclamation works were constructed through communal effort whereby the land was protected from tidal inundation by an earth bund constructed along the coast. However, these were inadequate, and together with the lack of proper maintenance they failed in time. Destruction of inland cultivation thus occurred.

Early drainage works involved the construction of coastal embankments to prevent saline water intrusion and the provision of facilities to allow removal of excess rainfall and runoff. Later, works in addition to reclamation were directed towards drainage improvement to permit intercropping.

Nowadays, the global climate change may increase the frequency and severity of storms. A very wide area of coastal wetlands and other lowlands could be inundated. Flooding would threaten the surroundings in term of their lives, agriculture, livestock, buildings and infrastructures. The salt water would advance landward into aquifers and up estuaries, and acts as a threat to the water supplies, ecosystems and agriculture in some areas.

In addition of present population growth and development, coastal areas worldwide are under increasing stress. Along with that, an increased exploitation of non-renewable resources is degrading the functions and values of coastal zones in many parts of the world. Consequently, the populated coastal areas are becoming more and more vulnerable to sea level rise and other impacts of climate change. Worst, even a small rise in sea level could have serious adverse effects.

Following the rainfall and storms which are not constant throughout the year, it is much afraid that it would affect the estuaries drainage physically and change a whole lot of the dynamic and coastal processes along the area. The flow and the volume are to be determined to find out at which point of the flow would affect the system. Also other physical changes would be observed accordingly.

This project is going to deal with hydraulics and physical characteristics of drainage and the morphology that will be affected by the tidal wave and heavy rainfall or storm surge.

1.1 Problem Statement

Sungai Dinding, Manjung has been a major resource of income for most of the villagers. Activity as such fishing is done daily as to support their lives. Almost all of the villagers own their own boat, and having the Sungai Dinding as path of their transportation. The activities as such are mainly affected by the tidal fluctuation occurs daily. On the other hand, the inland area is occupied by a large number of villagers and three (3) chalets commonly used to accommodate students coming for survey and other school or college activities. Meanwhile, during heavy rainfall, it is observed that a certain area will be flooded and could not be accessed. It may affect the surrounding area, such as the structures nearby and people’s activities.

Villager’s belonging also might be jeopardized from the direct or indirect effect of the drainage system inefficiency during peak conditions. Therefore, hydraulic and hydrology model analysis will be carried out in order to measure the effectiveness of current system in the area within three conditions, which are:

i. Tidal (ebbing and flooding);

ii. Heavy rainfall; and

iii. Combination of tidal and heavy rainfall.

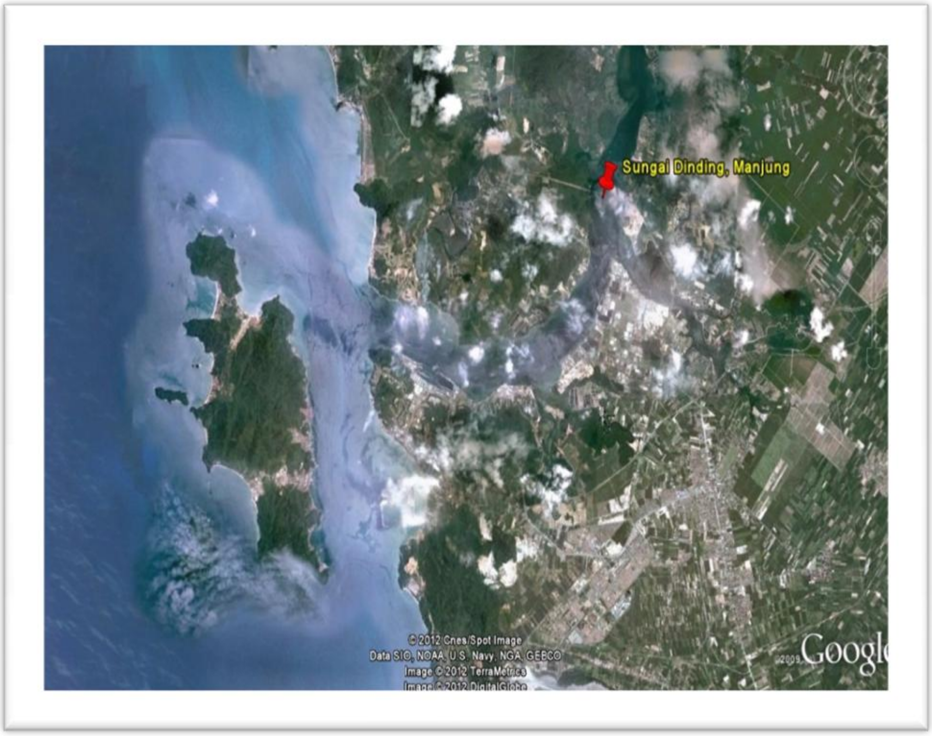

Figure 1.1: Site location

1.2 Objective

The project will investigate the implication of tidal wave and heavy rainstorm that would affect the drainage of estuaries. The impact assessed would be in:

1. To develop water surface profile of tidal channels in the estuary immediately before and after tidal reconnections
2. To identify the effect of tidal fluctuation and heavy rainfall towards the drainage system in the area.

1.3 Scope of Project

The following is the scope of my study:

i. The study will be done at Sungai Dinding, Manjung in Perak.

ii. Currents, water levels and the cross sectionals data collection will be collected during study. The current tidal and rainfall data is obtained from JPS in Manjung.

iii. HEC-RAS software will be used as a modelling tool to set up one-dimensional numerical model to model the changes in flow, water levels and sediment concentration.

CHAPTER 2
LITERATURE REVIEW

2.1 Study Area in Estuaries

Estuaries are a semi-enclosed coastal body of water, which has a free connection with the open sea, and within the sea water which is measurably diluted with freshwater coming from the land drainage (Pritchard, 1967). It is generally the tidal mouth of a river, and estuaries are often characterized by the sedimentation or silt carried in from terrestrial runoff and, frequently, from the offshore. The estuary usually fills and drains twice daily due to the diurnal tides. This tidal flushing fills of the estuary; its tributaries and adjoining tidal wetlands with brackish water on the flood tide and drains the water on the falling tide.

Estuaries are a dynamic ecosystem with connection to the open sea through which seawater enters accordingly to the rhythm of its tides. Fertile coastal lowlands, abundant marine resources, water transportation, aesthetic beauty and intrinsic values have long motivated coastal habitation. The coastal zone includes both the area of the land subject to marine influence and also the area of sea subject to land influence. They filter and process agricultural and industrial wastes and also buffer inland areas against the storm and wave damage.

A theory was introduced on flow distribution, which is expressed in Equation 2.1:

$$Qin \neq Qout \qquad \text{(Equation 2.1)}$$

Which means, the flow directed inward during flood and directed outward during ebb are not equal (within a tidal cycle). This difference caused a net flow of a small magnitude through the network as a second order effect (Sivakholundu, 2009)

2.1.1 Tidal Wave

One of the most obvious factors in estuary areas is the rise and fall of tides. Backwater effects caused by tides actions and the other factors can have a dominant influence on nearby drainage systems. The actual water level at a given location in tidal zones at a given time will be depended upon (DID, 2000):

i. Astronomical effects caused by the gravitational action of the sun and moon;

ii. Meteorological effects, including the atmospheric pressure variations and wind and wave set-up; and the effect of the surface gradients associated with flow pattern in the estuary.

The Figure 2.1 below shows the desirable range for outfall inert level following respective level of water surface.

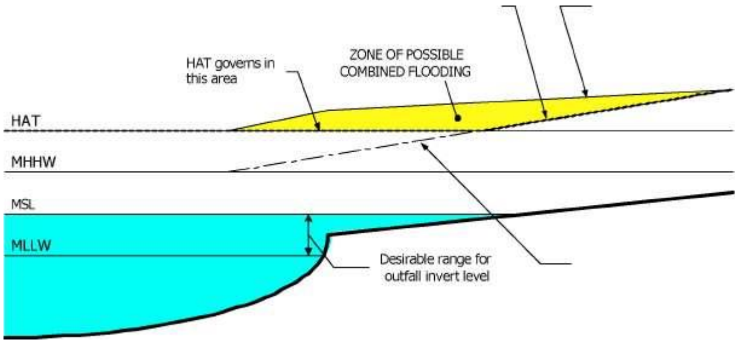

Figure 2.1: Tidal variations (Department of Irrigation and Drainage, DID, 2000)

The tidal variations occurs daily and the tidal cycle are approximately 12 hours long and tides flood about half of that time and ebb the half (Giannico and Souder, 2004). Its forcing affects aerial exposure; circulation patterns in tidal creeks, including the distribution of water properties such as sedimentation or erosion patterns and topographic evolution (Roegner, 2006).

Tidal forces influence them which tides are the regular rise and fall of the water level in the ocean are caused by the gravitational pull of sun and moon. During high tide, the ocean fills up into the estuary and the saltwater moves closer to the land. On the other hand, during the low tide, the estuary drains and the ocean is flowing back to be replaced by freshwater flowing from the land. These regulated movements of ocean water into and out of the estuary will cause the salinity at any given location within the estuary to continually change (LUMCON's Estuarine Development, 2006)

2.1.2 Heavy Rainfall and Storm Surge

In this project, another parameter that would be considered is the rainfall volume that will be affecting the drainage of estuaries as well. Malaysia country faces two monsoon winds seasons, which are the Southwest Monsoon occurrences from late May to September, and the Northeast Monsoon lasting from November to March. The Northeast Monsoon usually brings in much more rainfall compared to the Southwest Monsoon, originating from China and the North Pacific. The average rainfall is 250 cm (98 in.) in a year (Malaysian Meteorological Department, 2008).

Abnormal meteorological conditions can cause large deviations from the computed tidal levels. In this respect, the wind is the most important factor. Any variations that cause a rise or fall of the water level above or below he computed level through the action of wind is called a storm surge. The effect of a surge on expected tidal levels can be seen in Figure

1.2 below. It can be observed that the resulting water level is linear superposition of expected levels and surge levels (Saw, 2007). Storm surges have wave periods ranging from a few minutes to a few days and are categorised as long gravity waves in the same category as tidal waves. The effect of a storm surge is particularly severe when its arrival coincides with high tide (Vries, W.S; Huyskens, E.J, 1994).

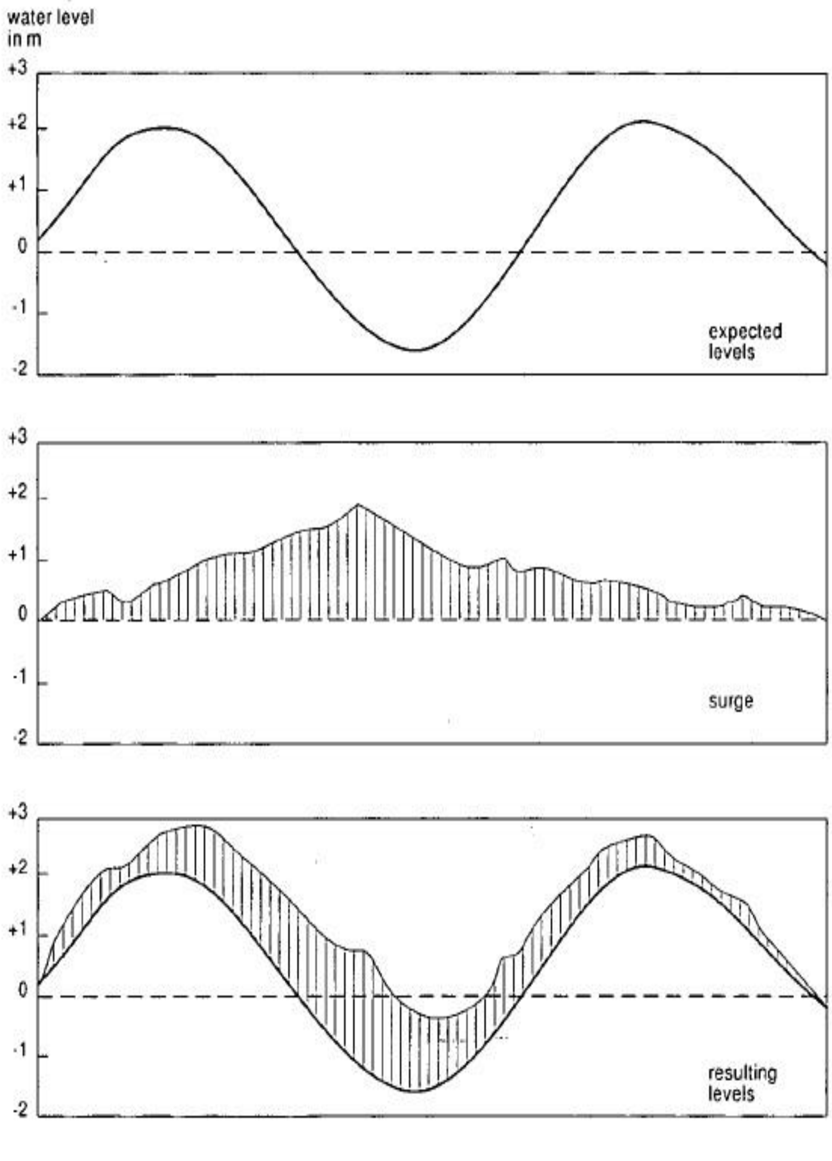

Figure 2.2: Effect of a surge on expected tidal levels

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Rainfall in Malaysia averages 25 cm or 98 inches annually, depending on location. A small amount of this excess (usually less than 1 inch per year) will percolates through the soil to recharge the deep groundwater aquifer systems (Karim and Mimura~~,~~ 2008). Most of the excess rainfall eventually returns to the ocean through surface water system of the streams, rivers, estuaries, and sounds.

Often the intense rainstorms result in surface runoff, while rainfall from milder storms usually infiltrates the soil. These sediments are restricting the rate of deep groundwater recharge. Consequently, excess rainfall that infiltrates the soil moves laterally above them as shallow groundwater flow until discharges to the surface water system (Heath, 1980).

Excess rainfall leaves a field either as surface drainage or as subsurface drainage. In some practices, it is hardly difficult to differentiate between the surface and subsurface drainage because of the outflow in drainage ditches or canals is actually a combination of the two. Drainage a system in which most of the outflow has drained through the soil profile is referred to as the subsurface drainage systems. While systems where surface runoff is the primary drainage mechanisms are called surface drainage systems (Evans and Skaggs, 1985).

These are a few of ecological impacts to the coastal areas as heavy rainfall occurred:

i. increase shoreline erosion;
ii. coastal flooding;
iii. inundate coastal wetlands and other lowlands;
iv. increase the salinity of estuaries and aquifers;
v. alter tidal ranges in rivers and bays;
vi. change the locations where rivers deposit sediment.

In general, the effects on shallow coastal ecosystems are strongly determined by local conditions. But if the accumulation of sediments cannot keep pace with rising waters, or if inland expansion of wetlands and intertidal areas is not possible because of infrastructure or a steeply rising coast, major impacts could occur.

The estuarine response to rising sea level is likely to be characterized by a slow but continually adjusting environment. Climate change may also provoke shifts in the hydrological regimes of coastal rivers and lead to increased discharge and sediment yields. These changes, together with a rise in sea level, could modify the shape and location of banks and channels. If no protective structures are built, wetlands can migrate inland; however, a net loss of wetlands would still result (Evans, 1996).

2.2 Traditional Drains

The main function of these drains has been to remove water from swamps, wetlands and low areas following rain or floods to improve agricultural productivity and reduce the negative effects of flooding. Only a very small proportion of coastal floodplain wetlands and estuaries remain unaffected by drainage works.

2.3 Current Drainage System

The purpose of drainage was to provide a mechanism to control the level of inundation of arable areas throughout the year. As such, drainage channels were designed to convey larger surface flows and reduce flooding that followed the more frequent and heavier rains. Removing the excess surface water created a number of benefits. (Seewraj, 2008) In a current drainage system, dikes and tide gates have been used worldwide for several countries to drain wetlands, both in estuaries and in the lower sections of rives, which are influenced by tides.

2.3.1 Dikes and Tidal Gates

Diking of estuarine wetlands and tidal channels which are intends to reduce or eliminate tidal influence has been extensively practice throughout the United States. The dikes are elevated earthen embankments which are raised along the tidally influenced channels in estuaries and coastal sections of the rivers to keep low-lying lands from being flooded during the high tides. In the discharge ends of the culverts, tide gates or flap gates are attached to control water flow. Tide gates are closed during incoming tides to prevent from the tidal waters to move upland. Meanwhile, they are open during outgoing tides to allow the upland water to flow through the culvert and thus into the receiving body of water. Tide gates are effective at maintaining low water levels (Giannico and Souder, 2004).

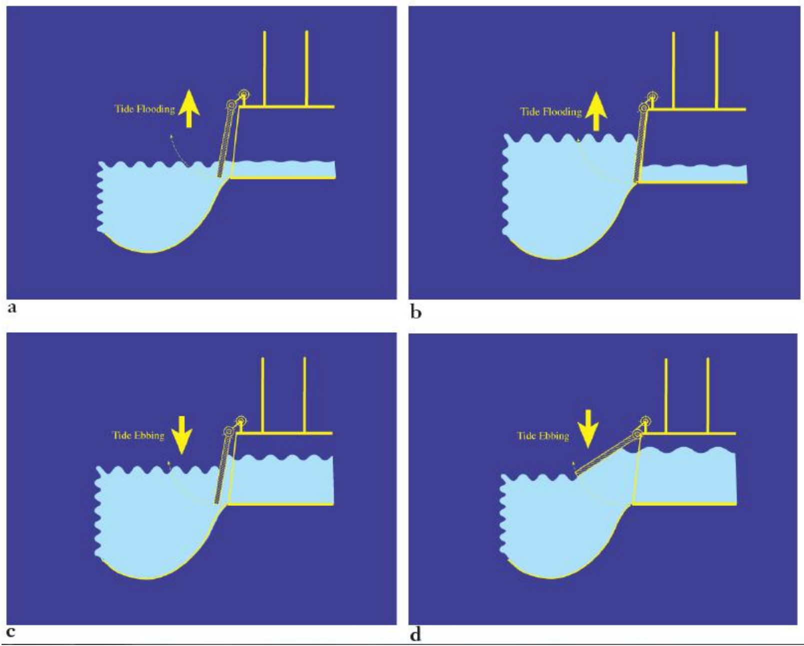

Figure 2.3: Tidal gates in flooding and ebbing condition (Giannico and Souder, 2004)

The rural drainage has not been designed to manage an ARI of 100 and there will therefore need to be careful consideration of the increased risk imposed by the rural drainage overtopping. One of the standard maintenance practices is to dredge the base of the drainage channel to remove vegetation and sediment build-ups. This tends to increase the depth and width of the channel. The impact of having a drainage system that is too efficient is that the ability of the catchment to retain floodwaters is reduced, thus increasing the potential for flooding downstream.

2.3.2 Geometry and Dynamics of Stream Channels

The stream channel is the passage for water being carried by the stream. The stream can constantly adjust its channel shape and path as the amount of water passing through the channel changes. The volume of water passing at any point on a stream is called discharge, which is measured in units of volume/time (m^3/sec).

i. Cross Sectional Shape – it varies with the position in the stream and discharge. The deepest parts of channel occur where the stream velocity is the highest. Both the width and depth are increasing downstream because of the discharge increases. While discharge increases, the cross sectional shape will change and the stream becoming deeper and wider.

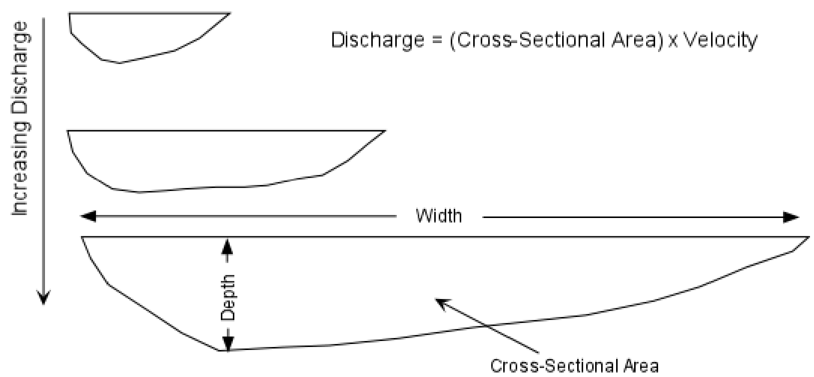

Figure 2.4: Cross-sectional shape varies with discharge

ii. Velocity - A stream's velocity depends on the position in the stream channel, while irregularities in the stream channel caused by resistant rock, and also stream gradient. Stream flow can either be laminar or turbulent, which an average linear velocity is generally greater in the laminar flow rather than in turbulent flow.

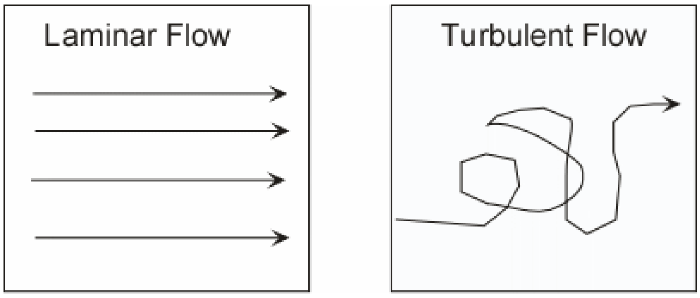

Figure 2.5: Laminar and Turbulent flow

iii. Discharge - The amount of water passing at any point in a given time:

$$\boldsymbol{Q = A \times V;} \qquad \text{(Equation 2.2)}$$

Where Q = Discharge (m^3/sec); A = Cross-sectional Area (m^2); V = Average Velocity (m/sec)

Along with the increasing water, the stream must adjust to its velocity and cross sectional area to form a balance. Discharge will increase as water is added through rainfall. As discharge increases, generally the width, depth, and velocity of the stream will also increase. Meanwhile increasing the depth and width of the stream may cause the stream to overflow its channel and results flooding.

Floods mainly occur because of the overly discharged of the stream and become too high to be accommodated in the normal stream channel. When the discharge becomes too high, the stream will tend to overtopping its banks and flooding the low-lying areas surrounding the stream. The areas that are flooded are called floodplains (River System and Causes of Flooding, 2011).

2.4 Problems of Drainage In Estuaries

Estuary is one of the most heavily populated areas throughout the world, which at about 60% of the world's population are living along estuaries and the coast. As a result, estuaries are enduring degradation by many factors, such as sedimentation from soil erosion from activities such as deforestation, poor farming practices; overfishing; drainage and also filling of wetlands. Other than that, development of land in the tidal zone may result in a number of drainage and storm water management problems (World's Most Impressive Estuaries: Definition, Benefits, and Problems).

A chain of flooding events had occurred late in 1323 at various locations within the Essex and Kent shores of the estuary which were caused by a constant extreme sea tides or surges. The unfortunate event was causing a serious damage to land and pasture, destructing fishing structures and mills and also some permanent loss to the marshland. Other than that, there was an increasing incidence of river-wall breaches which occurred after 1350 and lead to major and long-term flooding. While in 1365, the sea encroached over two miles there in a matter of days. By interpreting the chronological and also geographical pattern of the issue, it shows a major deterioration of the river condition as well as the sea-walls and drainage channels.

Disruption could also be severe in industrialized countries as a result of the high value of buildings and infrastructure. River water levels could rise and affect related infrastructure, bridges, port structures, quays and embankments. The higher water levels condition in the lower reaches of rivers and adjacent coastal waters may deteriorate natural drainage of adjacent land areas, and damaging the roads, buildings and agricultural land. While the potential impacts of sea level rise and climate change are much varied and uncertain. Nevertheless, there is still doubt that adaptive responses will be necessary.

Coastal areas generally are low-lying and thus vulnerable to flooding. High tides can decrease the elevation difference and further slow gravity drainage. Moreover, storm surges in coastal areas frequently occur during rainstorms, and can completely stop natural drainage. High water tables in coastal areas will also limit natural drainage. With water tables just below the land surface, a rainstorm can rapidly saturate the soil and raise the water table to the surface. The saturated soil increases runoff by decreasing the ability of water to percolate into the ground.

Coastal flooding can also be exacerbated by problems frequently not considered in designing the drainage system. Storm waves may overtop a seawall; and sediment and debris may block inlets, outlets, and storm sewer pipes and canals. During the worst storm surges, coastal areas may be completely inundated by the sea, leaving the drainage system ineffective until water levels have receded (Nicholls et al, 2007).

In theory, it would probably have been better to design for a combined rainfall and storm surge with a return period of 5 to 10 years. Some of the greatest potential impacts of climate effect on estuaries may occur in the changes of physical mixing characteristics caused by constant changes in freshwater runoff. While in Venice Lagoon, Italy, the combination of the sea-level rise, an altered sediment dynamics, and also the geological land subsidence has somehow lowered the lagoon floor, widened tidal inlets, submerging of tidal flats and islands, and causing the shoreline to retreat around the lagoon circumference.

Depending on the tidal characteristics, the availability of marine sediment, and also the rate of sea-level rise, the remaining of tidal flats may either be further drowned, or else their relative level in the tidal frame is maintained, as shown by a several tidal basins in the Dutch

Wadden Sea. A projected increase of tropical cyclones and other coastal storms intensity could also alter bottom sediment dynamics in the estuaries.

Dynamic coastal systems often show much complex and non-linear morphological response to the change. The erosion, transport and deposition mechanism of sediment often suggest significant time-lags, and also the morphological evolution of sedimentary coasts is the by-product of counteracting transport processes of sediment supply versus removal. A shoreline may adopt in equilibrium, whether in profile or plan form, where these processes are in balance. However, there are external factors, such as storms which often induce the morph dynamic change away from an equilibrium state (Leo and Van, 2004).

2.4.1 Erosion

The principal causes of erosion are floods, wind-wave action and tidal currents. Constant, small-scale erosion is caused by wind and wind-waves in the Estuary. This erosion is exacerbated by pedestrian traffic over the dunes. The Estuary limits direct access to the beach, forcing pedestrians to walk south along the dune face and around the lagoon to access the beach. This traffic inhibits the ability of natural vegetation to stabilize the dune and causes general sloughing of sand along the length of the dunes.

Large event erosion can be caused by wave run-up from the ocean and from erosive, high-velocity storm water flows from the creek. During the large storm events of 1986 and 1997, wave action in combination with creek flow caused major slides and subsequent soil loss of the dunes. The ongoing effects of offshore winds push the creek flow south; parallel with the dune and beach, causing erosion of the toe of the dune.

Additionally, these erosion sources damage the dune from different directions. Some attack the dune from the front, while others run parallel to the dune face. The combination of different erosion sources coming from different directions requires multiple protection measures working together to stop the erosion.

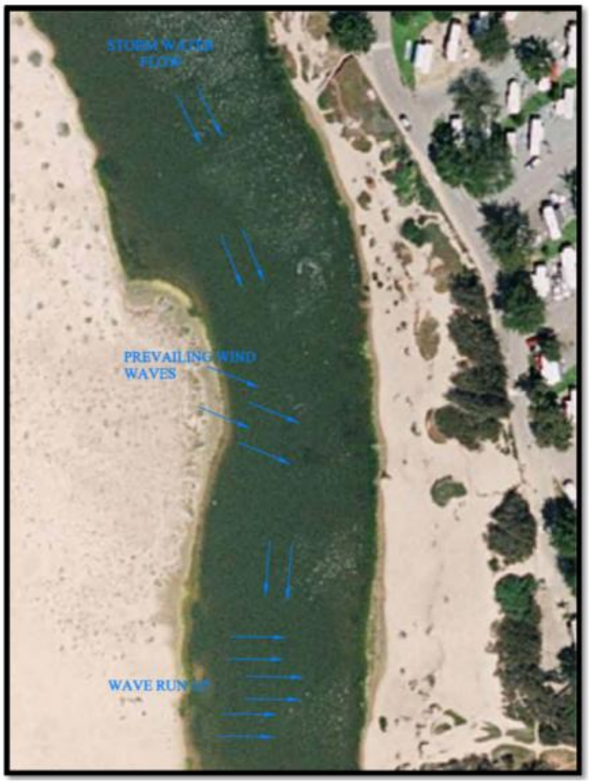

Figure 2.6: Illustration of Causes of Erosion

2.4.2 Sedimentation

When flow passes a channel, the velocities are decreasing due to the increase of water depths in the channel and hence decreasing the transport capacity of bed load and also suspended load. As a result, the bed-load particles and an amount of suspended sediment particles will be deposited in the channel.

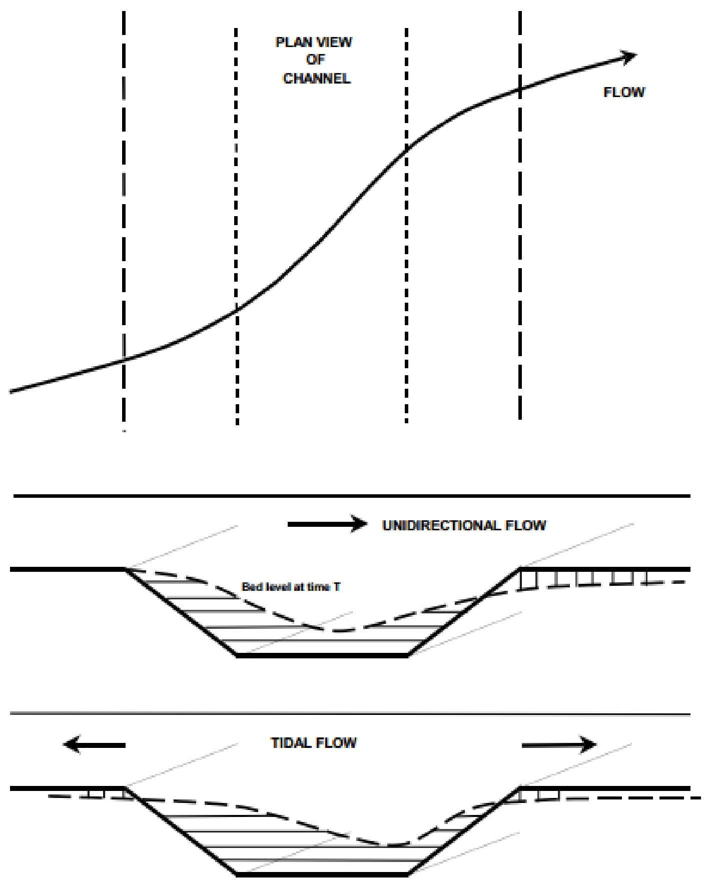

Figure 2.7: Channel Sedimentation (plan view and cross-section)

When there are waves present, this process is enhanced due to the sediment stirring action of wave motions in the near-bed region which results in a larger sediment concentration which are subsequently transported by the flow.

Factors of enhancing sedimentation are:

i. Deep and wide channel;
ii. Orientation almost normal to the flow;
iii. Strong flows and large waves passing the channel;
iv. Fine sediment (fine sand and mud);

Natural navigation channels in the estuaries are often suffers from the generation of shoals at the transition of the flood-dominated and ebb-dominated channels.

CHAPTER 3
METHODOLOGY

*3.1 **Site Description***

Sungai Dinding, Manjung is located in Sitiawan with Raja Permaisuri Bainun Bridge crossing the estuary. The length of the bridge is approximately 1.25 kilometers of which 930 metres of it is over the Dinding River. The area is a tide-nominated estuary with village and residential area of Kampung Baru Sitiawan is located along the Sungai Dinding.

*3.2 **Data Collection***

1. Collecting data for flow velocity
   - Electromagnetic Current Meter (ECM) was used to measure the flow velocity of water, a device that normally senses horizontal current flow along two axes perpendicular to each other.
   - Typical ECM measures the current by inducing magnetic field around a spherical sensor head, thus measuring the electromotive force resulting from a conductor or water moving through the field. The best results are achieved after careful calibration of ECM in a flume or other controlled flow environment.

2. Collection data of water depth
   - Based on the semidiurnal condition of tide in the site area, water depths were taken for at least 4 times per day respected to each low and high tidal condition.
   - Water depth measured using multi-probe or SONDE which acts under the ‘Pressure method’. It can facilitate measurements as far as 100 meters below the water surface.
   - Two SONDE equipments were used in taking the data to make sure the accuracy.

3. Measurement of cross-section width
   - Distance between each pier measured using a distometer to get the whole width of the section.

4. Tidal height
   - Referring to the tidal table, data of tidal height collected on each of daily high and low tide.
   - The estimated low and high tide is obtained from the data prepared by the meteorological department.

5. Draw the cross-sectional profile.
   - By using the data of water depth measured, a rough sketch of the cross-sectional profile is done.

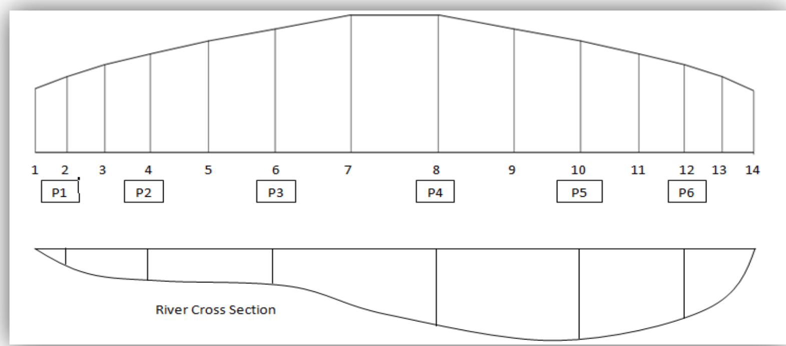

Figure 3.1: Cross-sectional Profile

6. Rainfall data
   - Actual rainfall data was obtained from the JPS of the site location area.

*3.3 **Observation***

- A continuous observation will be done towards the behaviour of drainage system in the area, especially under the condition of:

  i) Low tide

  ii) High tide

  iii) Heavy rainfall

  iv) Low rainfall

3.4 ***Software simulation using HEC-RAS software***

i) Geometric data entered

- Schematic of the river system was drawn

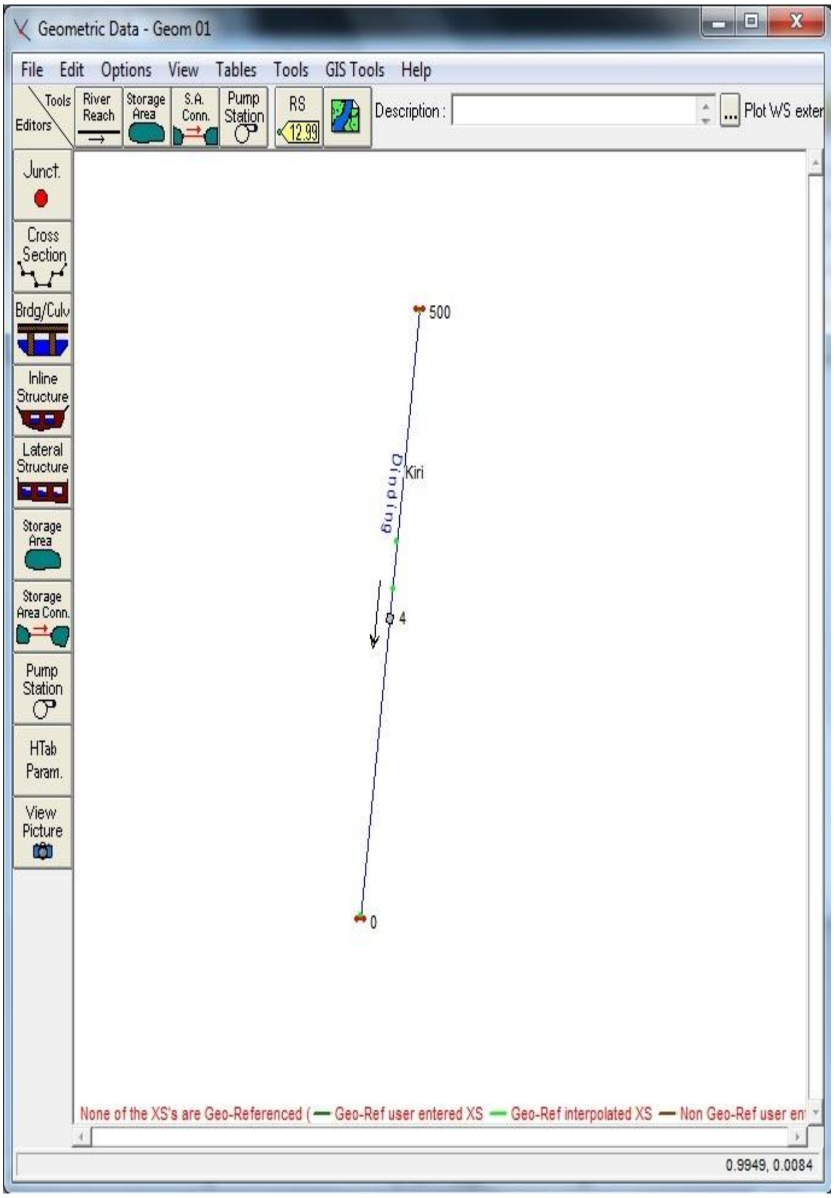

Figure 3.2: Schematic of the river system

- cross section data entered
  - Select a river and a reach to work with and add a new cross section. Cross sections are located from upstream to downstream.
  - Enter all of the data for this cross section as shown in Figure 3.2 and Figure 3.3.
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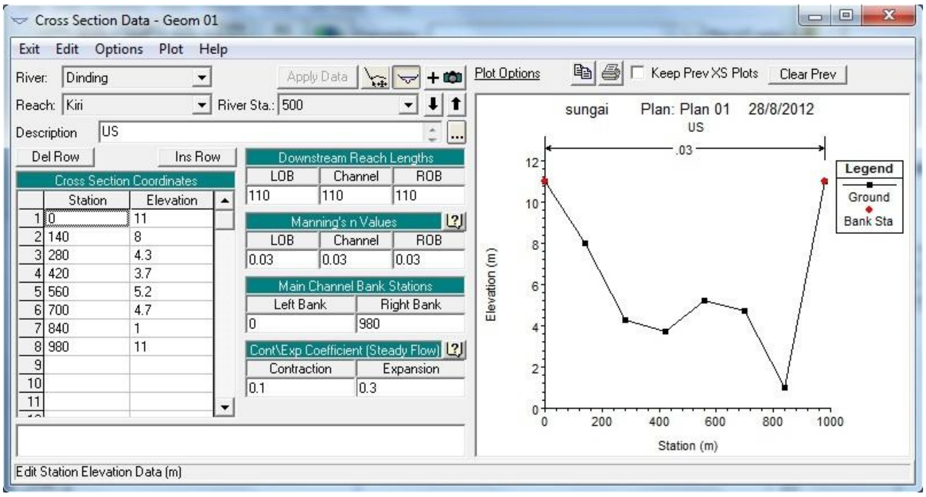


Figure 3.2: Cross section data input (upstream boundary)

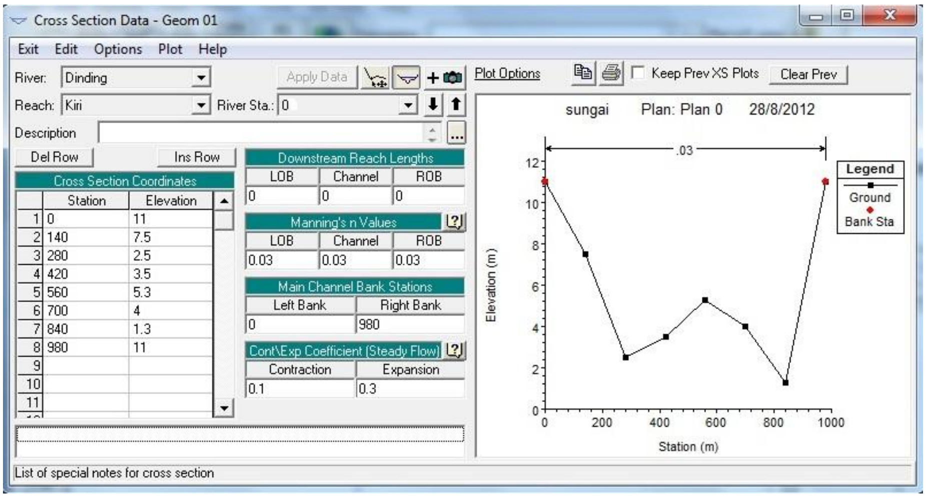


Figure 3.3: Cross section data input (downstream boundary)

- As this project is concentrating on two locations of cross sections, the data input done for both locations as well.

ii) Steady flow data entered

- Flow data are entered from upstream to downstream for each reach. At least one flow rate must be entered for every reach in the river system.

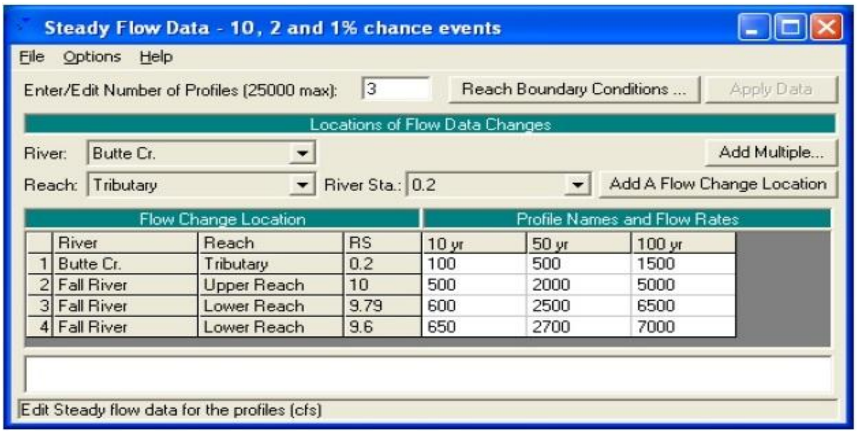


Figure 3.3: Steady flow data input

- Once a flow value is entered at the upstream end of a reach, it is assumed that the flow remains constant until the flow value is encountered within the reach.

iii) Boundary condition entered

- It is necessary to establish the starting water surface at the ends of the river system.
- The boundary conditions editor contains a table listing every river and reach. Each reach has an upstream and downstream boundary condition.

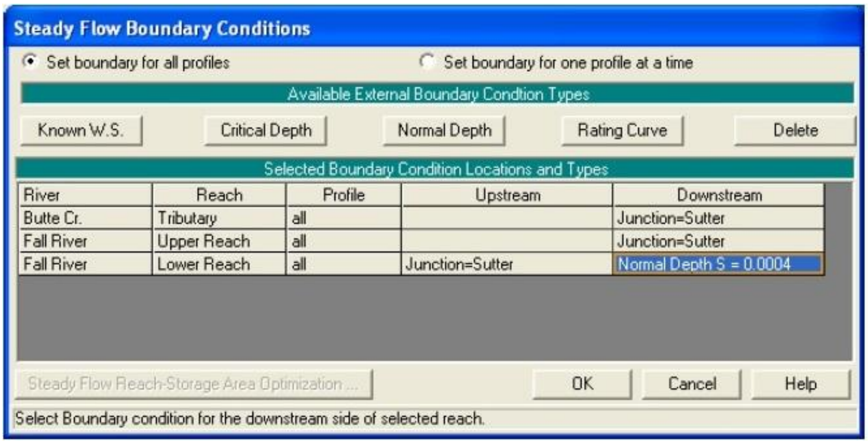


Figure 3.4: Boundary condition

- There are four types of boundary conditions which are the known water surface elevations, critical depth, normal depth, and rating curve.

iv) Hydraulic calculations performed

- This is to calculate the steady water surface profiles.
- Put together a 'Plan' which defines which geometry and flow data are to be used, as well as providing a title and short identifier for the run.

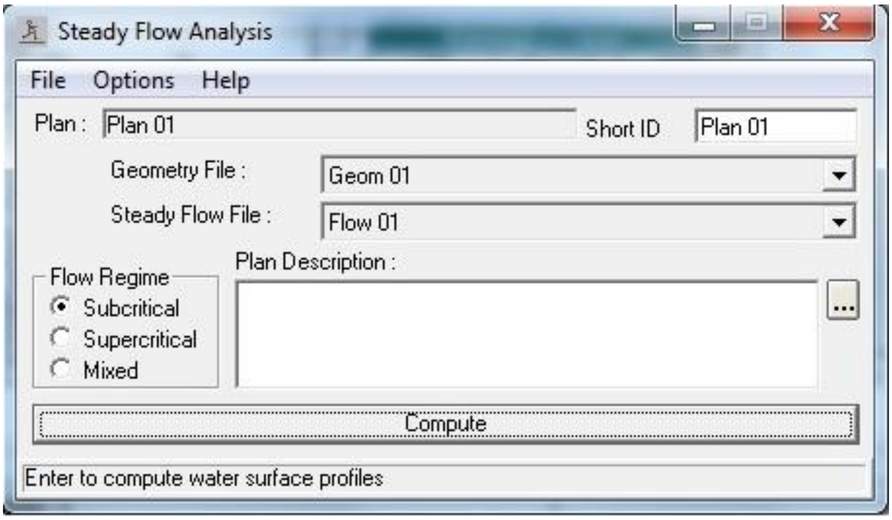


Figure 3.5: Hydraulic calculation

- Select 'New Plan' and select the desired flow regime for which the model will perform calculations.
- Compute the simulation.

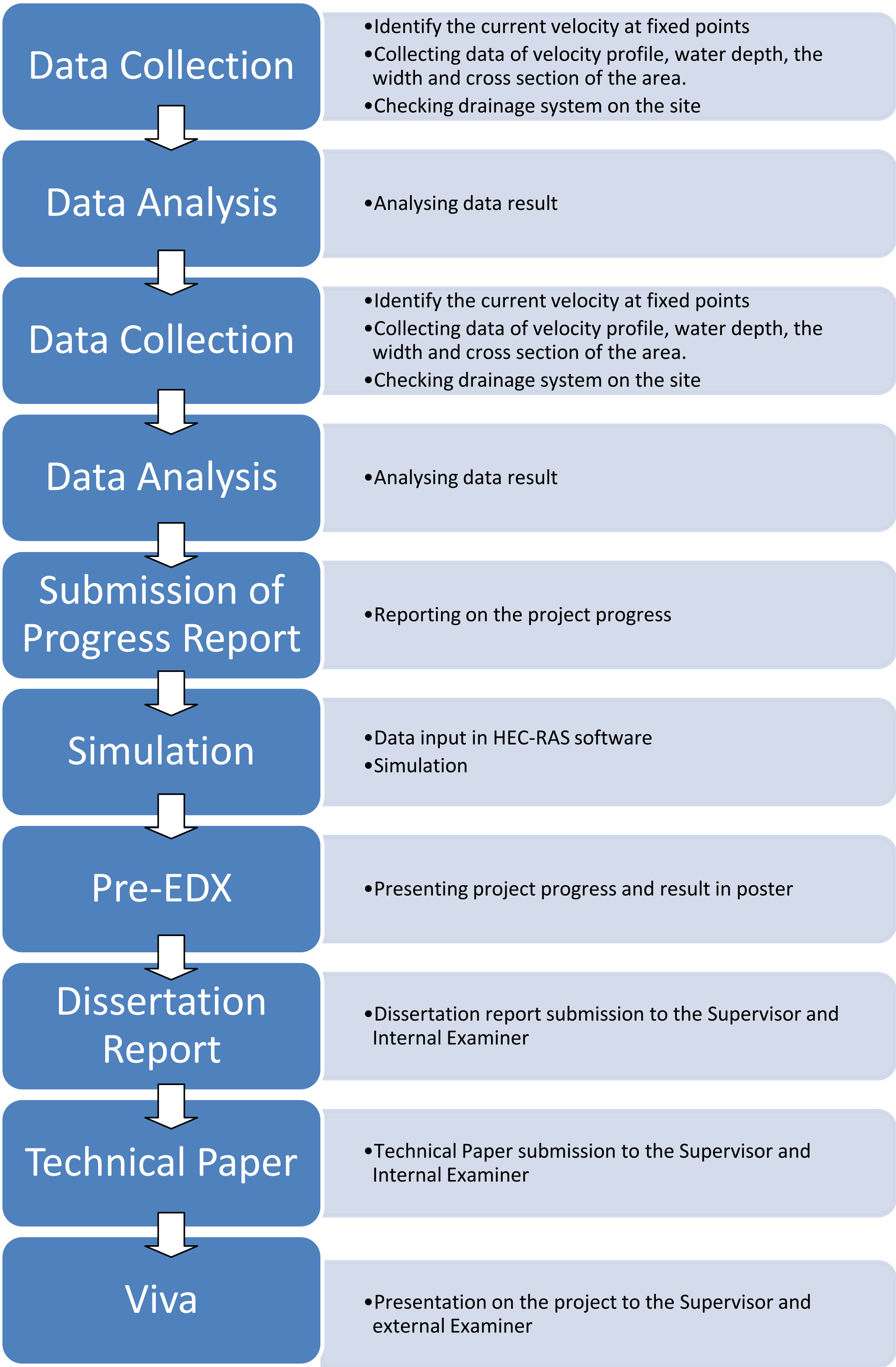
v) Viewing graphical and tabular results

*3.5 **Tools***

Equipment	**Purpose**
SONDE	To measure water depth
Electromagnetic Current Meter	Determine water velocity
Distometer	Find width of the river
Softwares	**Purpose**
HEC-RAS	Simulates flow and cross-section

Table 3.1: Tools used in Project

3.6 ***Flow Chart***



*3.7 **Gantt Chart***

i) FYPI

Activities	**Week**													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of FYP Topic														
Confirmation of FYP Topic														
Retrieve relevant references														
Planning the project flow														
Submit Extended Proposal and site selection						X								
Site work and collecting data (Part I)														
Simulate data in MIKE 11														
Viva and Progress Evaluation									X					
Site work and collecting data (Part II)														
Simulate data in MIKE 11 and data analyzing														
Submit Interim Draft Report													X	
Submit Interim Report														X

ii) FYPII

Activities	**Week**													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Site work and data collection (Part III)														
Data Analysis														
Site work and data collection (Part IV)														
Data Analysis														
Submission of Progress Report														
Simulation Data														
Pre-EDX														
Submission of Draft Report														
Submission of Dissertation (Softbound)														
Submission of Technical Paper														
Oral Presentation														
Submission of Project Dissertation (Hardbound)														

4 RESULT AND DISCUSSION

4.1 Data Analysis

Data were gathered from four last trips done to the site area. The results and data analysis are as shown in Appendix A for water elevation data and Appendix B for water velocity data.

Based from the graphs made, the water elevation consistently changes according to its respective high and low tide. The areas of time which high tides occur are as follows:

High Tides	6 AM and 6 PM
Intermediate	10 AM and 10 PM
Low Tides	2 PM

Table 3.2: Observed High and Low Tides Time of Occurrences

Out of the four data collections done, there were only two rainfall conditions occurred which were on the 1st and 4th trips. Surface runoff is mostly affected by the rainfall occurrence and the ebbing also flooding of the water flow.

Other than that, the water velocity is not very constant, which is most possibly occurred because of a very wide cross section of the river. At the very first pier the water velocity is quite strong, as the cross section area is much smaller compared to the other piers cross sections.

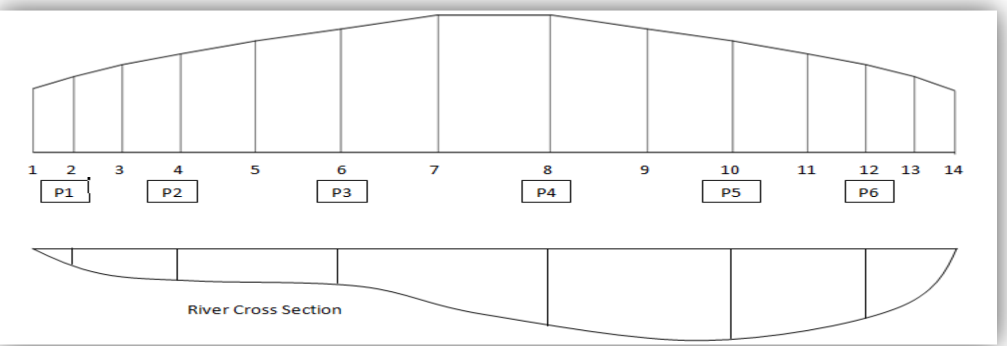


Figure 4.1: River cross-section

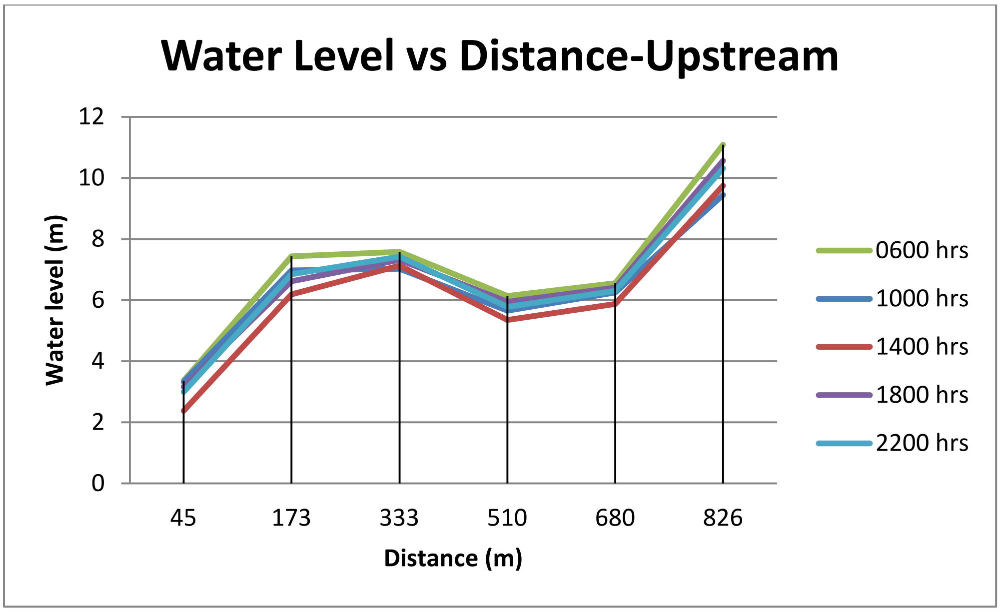


Figure 4.2: Graph of water level vs. distance for upstream

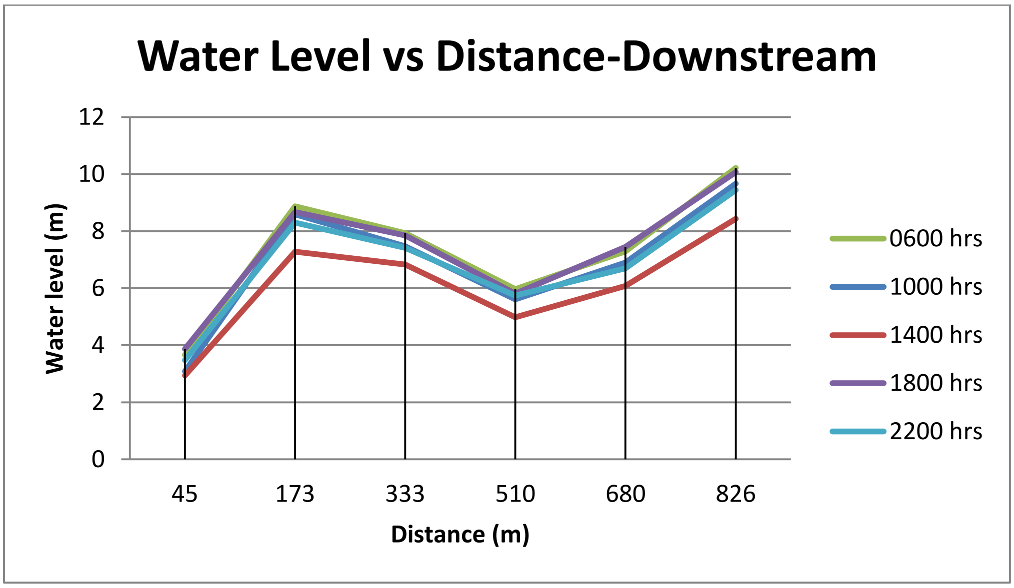


Figure 4.3: Graph of water level vs. distance for downstream

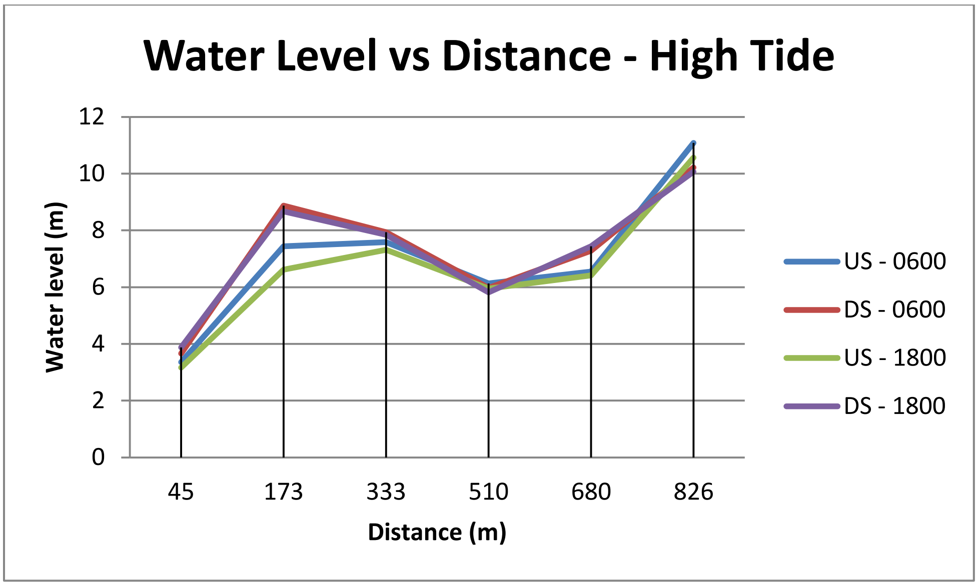


Figure 4.4: Graph of water level vs. distance during high tide

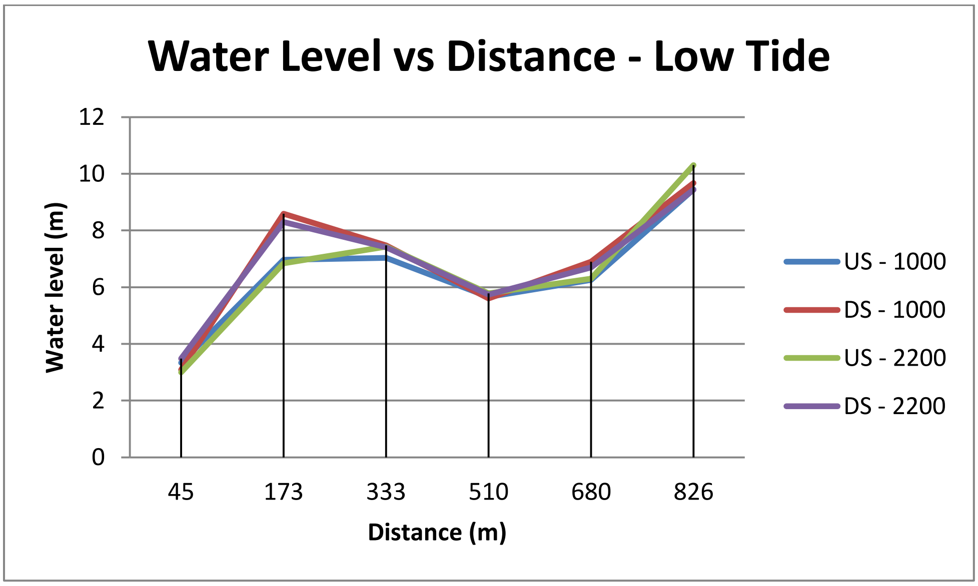


Figure 4.5: Graph of water level vs. distance during low tide

From the graphs shown above, the water levels along high tide occurrence are much higher than during the low tide occurrence. Although the differences of the water level have not much difference in value, the maximum high tide could be taken as in 0600 hours every day. Therefore, it is taken as the critical value of high tide condition used in the HEC-RAS Simulation.

4.1.1 Calculation of water total discharge using the Mean and Mid Section Method

HIGH TIDE

UPSTREAM (Mean Section Method)

Distance (m)	Width (m)	D(m)	Dave	V0.6D	V0.2D	V0.8D	Vavg	A	Q
0		0		-					
	45		1.449				0.07	65.205	4.56435
45		2.897		0.139					
	128		4.829				0.122	618.112	75.40966
173		6.761		-	0.042	0.166			
	160		7.02				0.101	1123.2	113.4432
333		7.278		-	0.039	0.156			
	177		6.523				0.108	1154.571	124.6937
510		5.768		-	0.048	0.19			
	170		6.023				0.133	1023.91	136.18
680		6.278		-	0.059	0.235			
	146		8.234				0.154	1202.164	185.1333
826		10.19		0.161					
	104		5.095				0.081	529.88	42.92028
930				-					
									682.3444

UPSTREAM (Mid Section Method)

Distance (m)	Width (m)	D(m)	V0.6D	V0.2D	V0.8D	Vavg	A	Q
0	45	0						
45	128	2.897	0.139			0.139	370.816	51.54342
173	160	6.761		0.042	0.166	0.104	1081.76	112.503
333	177	7.278		0.039	0.156	0.098	1288.206	126.2442
510	170	5.768		0.048	0.19	0.119	980.56	116.6866
680	146	6.278		0.059	0.235	0.147	916.588	134.7384
826	104	10.19	0.161			0.161	1059.76	170.6214
930	-							
								712.3371

DOWNSTREAM (Mean Section Method)

Distance (m)	Width (m)	D(m)	Dave	V0.6D	V0.2D	V0.8D	Vavg	A	Q
0		0							
	45		1.725				0.063	77.625	4.890375
45		3.45		0.125					
	128		5.955				0.125	762.24	95.28
173		8.46			0.05	0.198			
	160		8.035				0.114	1285.6	146.5584
333		7.61			0.041	0.165			
	177		6.655				0.114	1177.935	134.2846
510		5.7			0.05	0.2			
	170		6.34				0.135	1077.8	145.503
680		6.98			0.058	0.233			
	146		8.34				0.135	1217.64	164.3814
826		9.7		0.124					
	104		4.85				0.062	504.4	31.2728
930									
									722.1706

DOWNSTREAM (Mid Section Method)

Distance (m)	Width (m)	D(m)	V0.6D	V0.2D	V0.8D	Vavg	A	Q
0	45	0						
45	128	3.45	0.125			0.125	441.6	55.2
173	160	8.46		0.05	0.198	0.124	1353.6	167.8464
333	177	7.61		0.041	0.165	0.103	1346.97	138.7379
510	170	5.7		0.05	0.2	0.125	969	121.125
680	146	6.98		0.058	0.233	0.146	1019.08	148.7857
826	104	9.7	0.124			0.124	1008.8	125.0912
930	-							
								756.7862

LOW TIDE

UPSTREAM (Mean Section Method)

Distance (m)	Width (m)	D(m)	Dave	V0.6D	V0.2D	V0.8D	Vavg	A	Q
0		0							
	45		1.449				0.051	65.205	3.325455
45		2.897		0.101					
	128		4.829				0.122	618.112	75.40966
173		6.761			0.057	0.228			
	160		7.02				0.137	1123.2	153.8784
333		7.278			0.053	0.211			
	177		6.523				0.145	1154.571	167.4128
510		5.768			0.063	0.252			
	170		6.023				0.15	1023.91	153.5865
680		6.278			0.057	0.229			
	146		8.234				0.168	1202.164	201.9636
826		10.19		0.192					
	104		5.095				0.096	529.88	50.86848
930									
									806.4448

UPSTREAM (Mid Section Method)

Distance (m)	Width (m)	D(m)	V0.6D	V0.2D	V0.8D	Vavg	A	Q
0	45	0						
45	128	2.897	0.101			0.101	370.816	37.45242
173	160	6.761		0.057	0.228	0.143	1081.76	154.6917
333	177	7.278		0.053	0.211	0.132	1288.206	170.0432
510	170	5.768		0.063	0.252	0.158	980.56	154.9285
680	146	6.278		0.057	0.229	0.143	916.588	131.0721
826	104	10.19	0.192			0.192	1059.76	203.4739
930	-							
								851.6618

DOWNSTREAM (Mean Section Method)

Distance (m)	Width (m)	D(m)	Dave	V0.6D	V0.2D	V0.8D	Vavg	A	Q
0		0							
	45		1.725				0.063	77.625	4.890375
45		3.45		0.125					
	128		5.955				0.122	762.24	92.99328
173		8.46			0.048	0.191			
	160		8.035				0.131	1285.6	168.4136
333		7.61			0.057	0.228			
	177		6.655				0.144	1177.935	169.6226
510		5.7			0.058	0.231			
	170		6.34				0.147	1077.8	158.4366
680		6.98			0.06	0.239			
	146		8.34				0.137	1217.64	166.8167
826		9.7		0.125					
	104		4.85				0.063	504.4	31.7772
930									
									792.9504

DOWNSTREAM (Mid Section Method)

Distance (m)	Width (m)	D(m)	V0.6D	V0.2D	V0.8D	Vavg	A	Q
0	45	0						
45	128	3.45	0.125			0.125	441.6	55.2
173	160	8.46		0.048	0.191	0.12	1353.6	162.432
333	177	7.61		0.057	0.228	0.143	1346.97	192.6167
510	170	5.7		0.058	0.231	0.145	969	140.505
680	146	6.98		0.06	0.239	0.15	1019.08	152.862
826	104	9.7	0.125			0.125	1008.8	126.1
930	-							
								829.7157

	High		**Low**	
	US	**DS**	**US**	**DS**
Mean	682.34	722.17	806.44	792.95
Mid	712.34	756.79	851.66	829.72

Table 4.1: Total Discharge, Q calculated

Based on the result of total discharge, Q calculations, it is summarized that the value is highest during low tide.

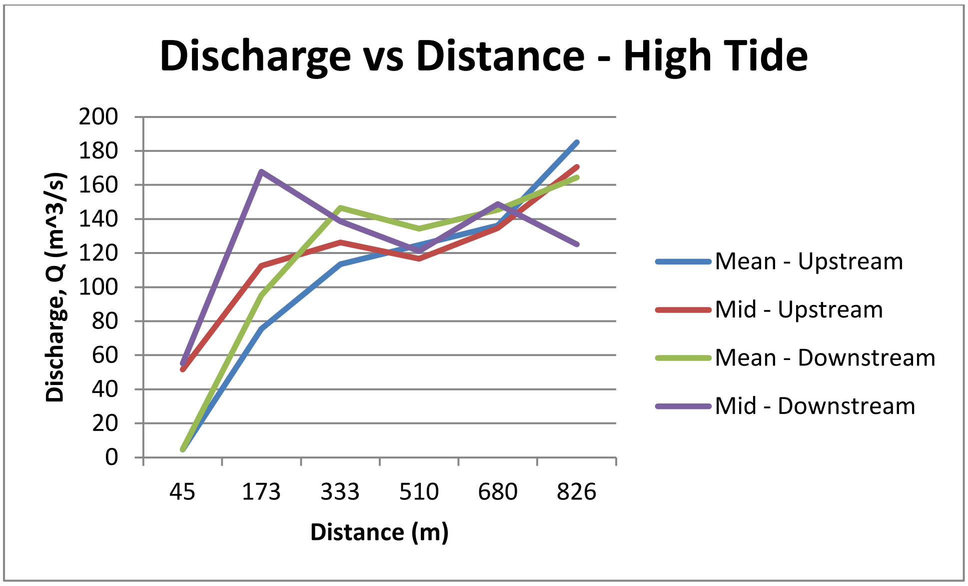


Figure 4.6: Graph of discharge vs. distance during high tide

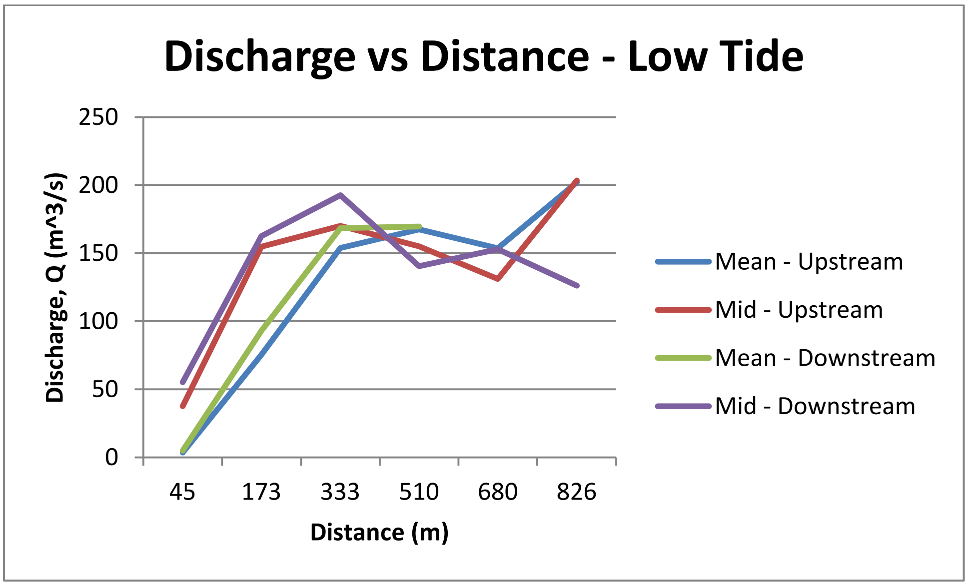


Figure 4.7: Graph of discharge vs. distance during low tide

Meanwhile, the rainfall occurrence is being expressed as the probability of a particular rainfall amount for a specified duration being equalled or exceeded in any 1 year period. During the period of project, it is unfortunate that it has not been undertaken during a rainy season. Figure 4.8 shows the resulting ARI graph from data of rainfall gained.

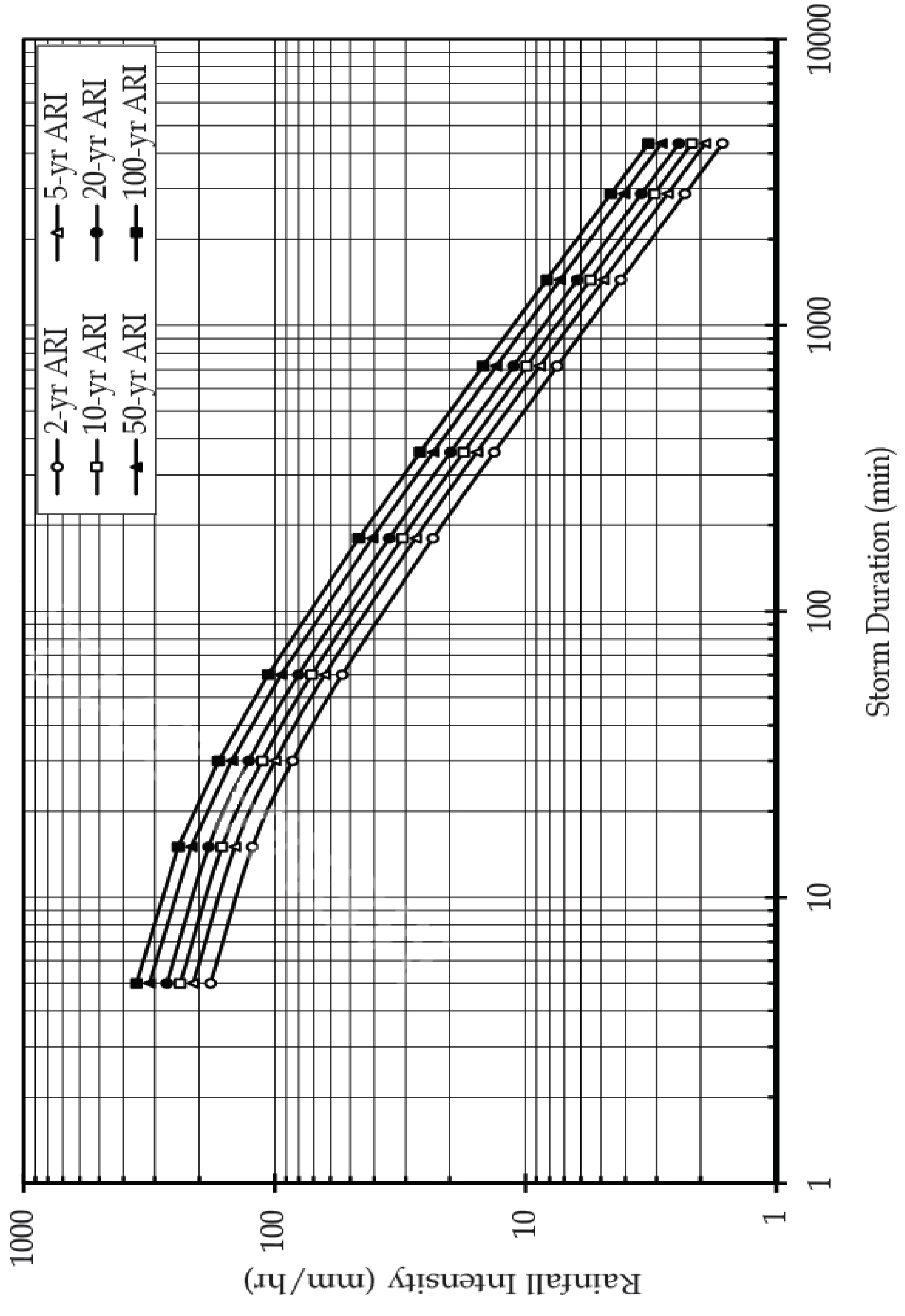


Figure 4.8: Graph of Average Recurrence Interval (ARI) of the rainfall intensity at JPS Sitiawan Rainfall Station - 4207048

4.2 Drainage System in Site Area

Pictures below shows the drainage system observed in the study area. Earth drainage was found to be very shallow and unorganized. While the underground systems are assisted with culverts and piping installed underneath.

Figure 4.9: Earth drainage in site area

Figure 4.10: Concrete drainage connected to the earth drains

Figure 4.11: Culverts and piping

Figure 4.12: Drains

Figure 4.13: Condition of drain after a short rainfall occurrence

Figure 4.11 shows the culverts found which were filled with litters and sediments, causing some of them to incurred blockage of the water flow, might be reducing the efficiency of the system of drainage. It seems that the drainage was never been maintained before. During the high peak of water level in the estuary system, the drainage should be able to contain the runoff generated.

On the other hand, Figure 4.12 shows concrete drainages systems applied in the area. Basically there were not much of concrete drainages in the area as it is not practically planned and developed in such a way that the surrounding is mostly rural.

While from Figure 4.13, the drains were observed after short rainfall duration occurred, which the drains were almost full with runoff volume. These are the only drains found in the area of study area. The rest are mostly underground system including the piping and culverts. As far as the observation of drainage systems in the area of study has been done, not much of knowledge on the flooding events occurrences is known.

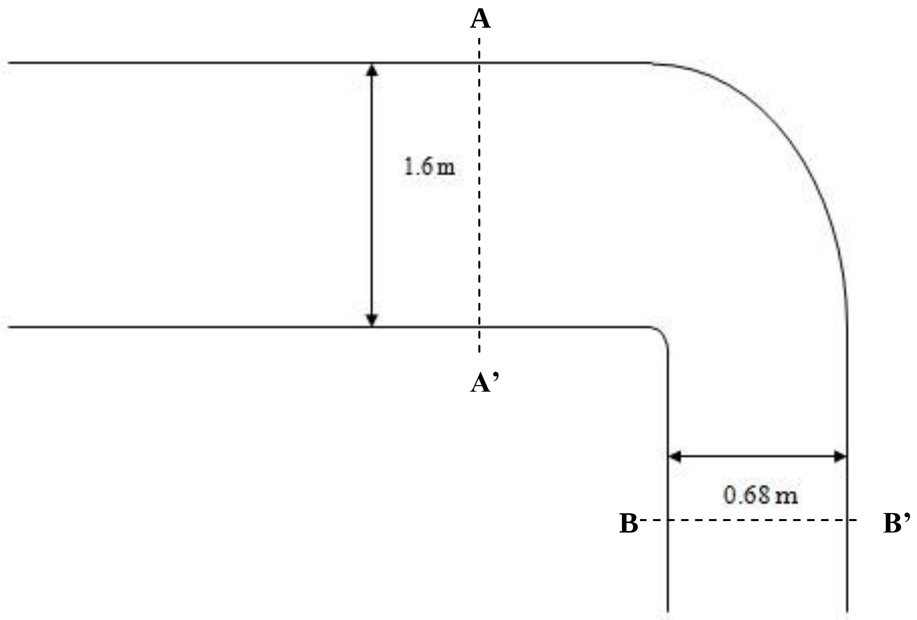
An event of short rainfall was observed and resulting a very high volume of runoff in the drainage. During the peak condition, a very large numbers of people live on floodplains might be affected by flooding and jeopardizing the properties and their lives.

A much systematic planning of the drainage design in the area should be implemented. The design life of the system might be accommodating the future undertakings of environmental and weather state.

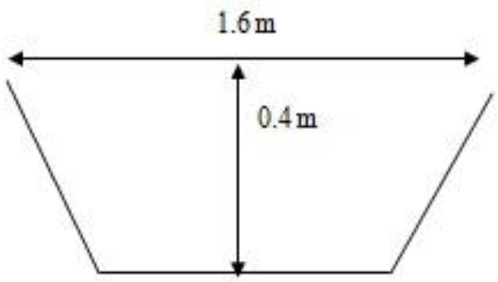
4.2.1 Dimensions of Drainage System

Point 1 (Earth Drain)

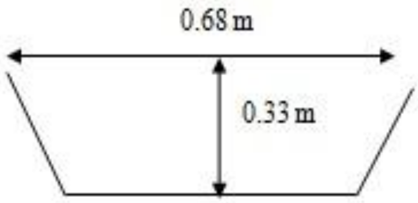
Plan View



Cross-section view



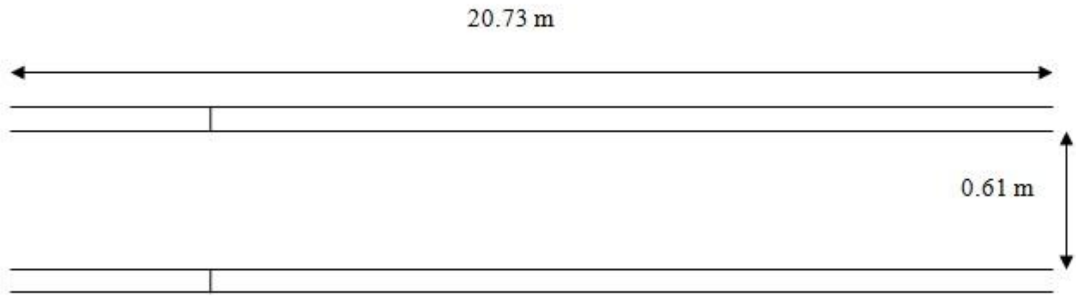
A - A’



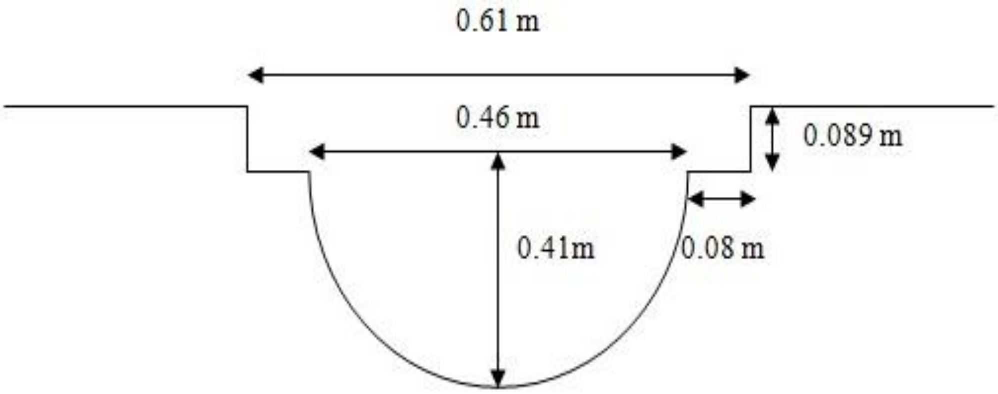
B – B’

Point 2 (Concrete drain)

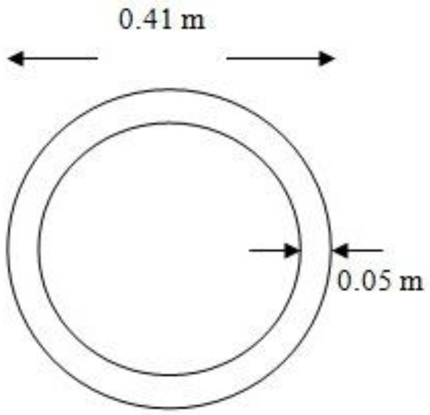
Plan View



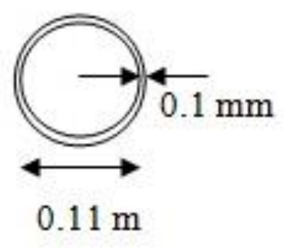
Cross-section view



Culvert dimension

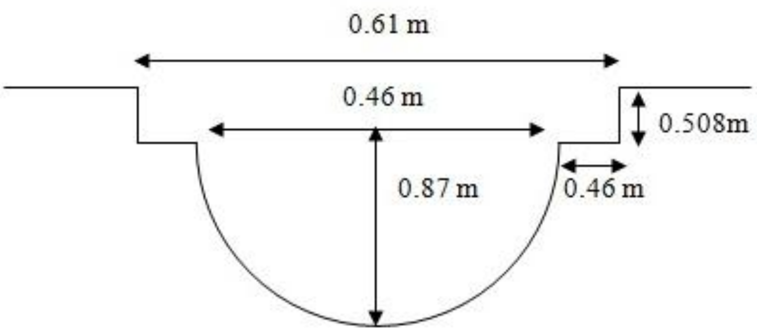


Piping dimension



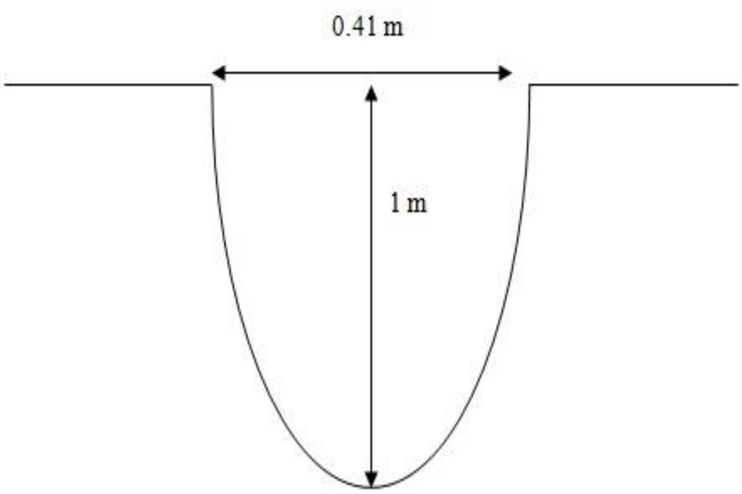
Point 3 (Concrete drain)

Cross-section view



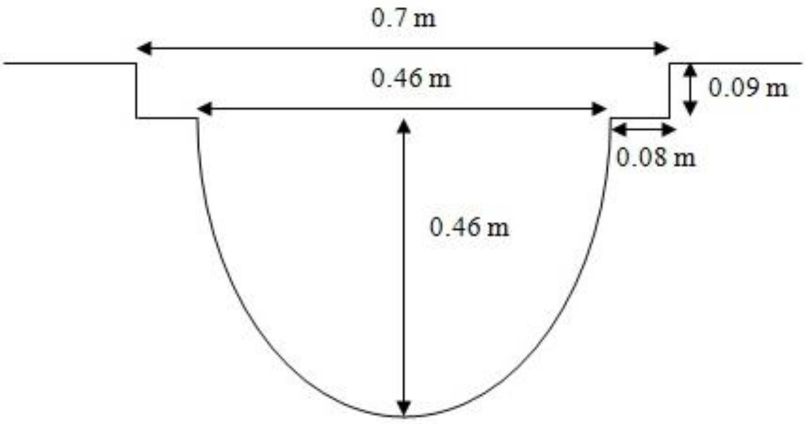
Point 4 (Concrete drain)

Cross-section view



Point 5 (Concrete drain)

Cross-section view



4.3 HEC-RAS Analysis

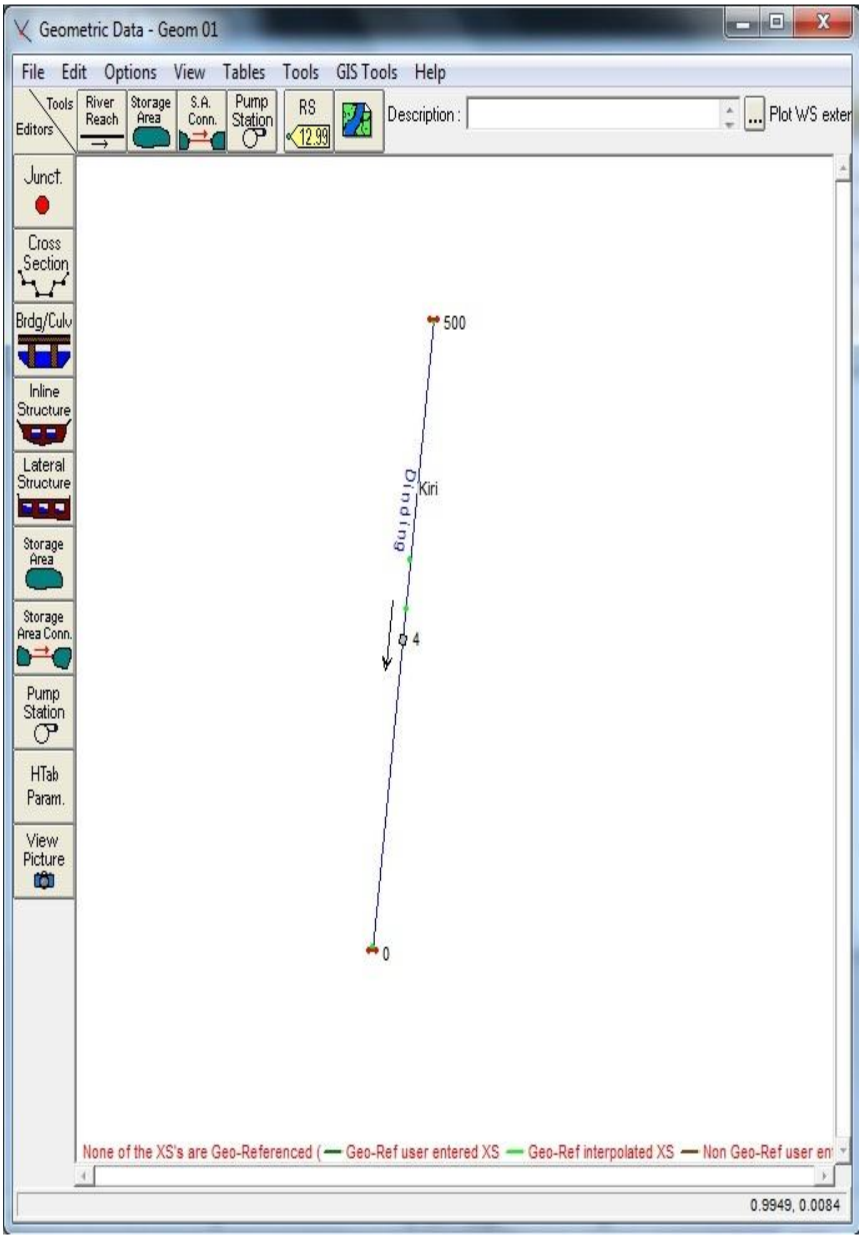


Figure 4.14: Input of Data Geometry

Figure above represents the sketch of river and reaches including the points of the data collection conducted. Upstream (river station: 250) and downstream side (river station: 0) are separated by a bridge crossing them at point 4 in the figure.

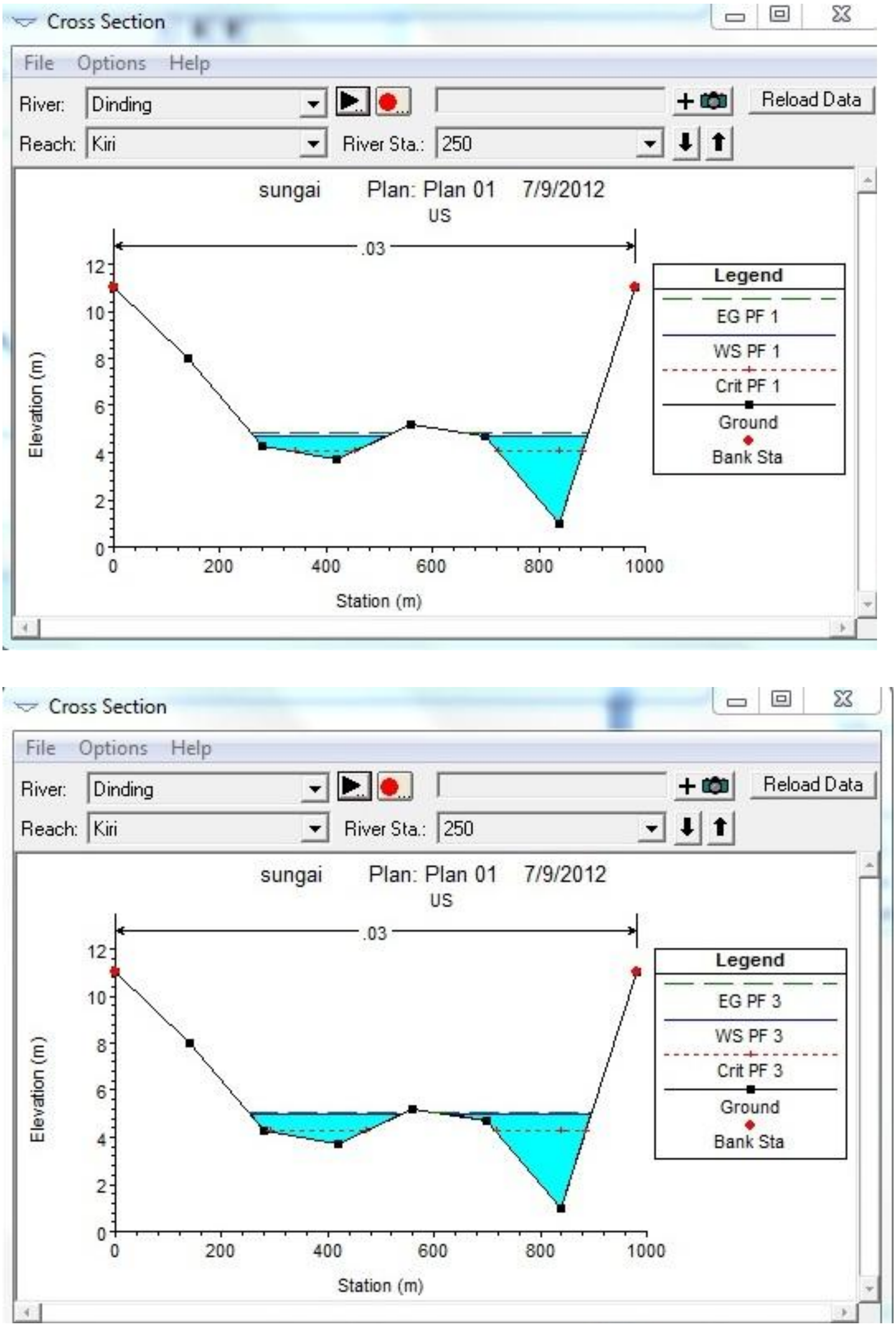
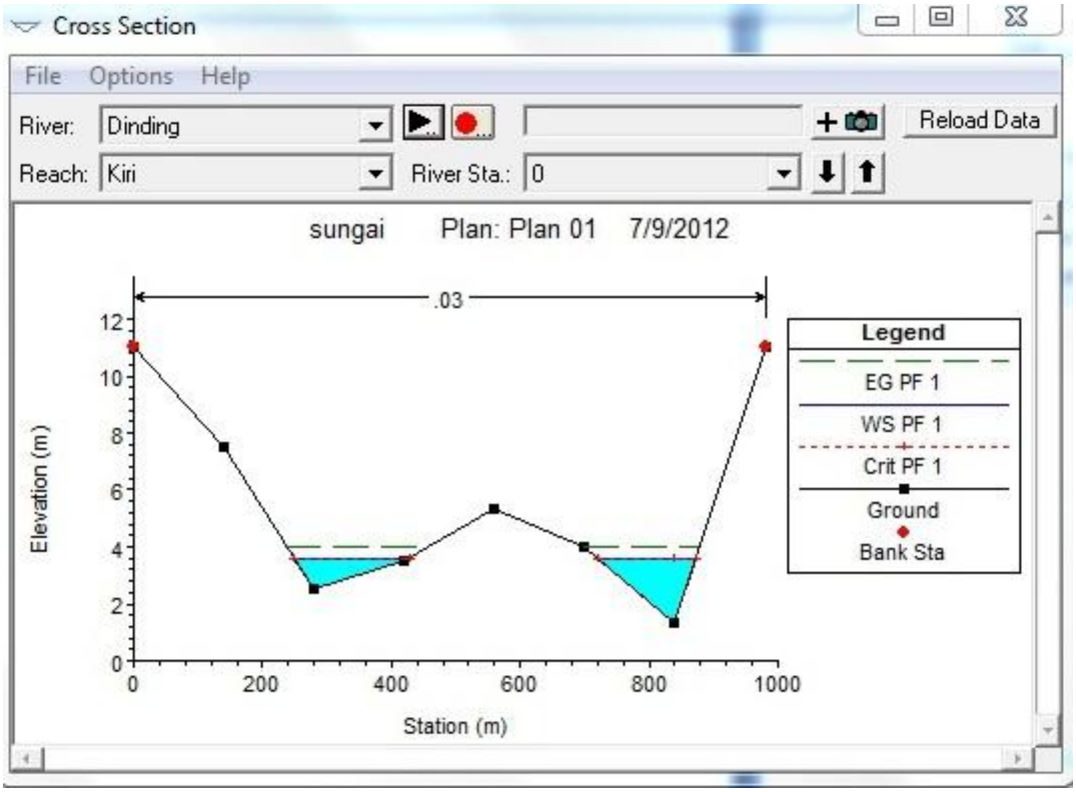


Figure 4.15: River cross-section of Upstream



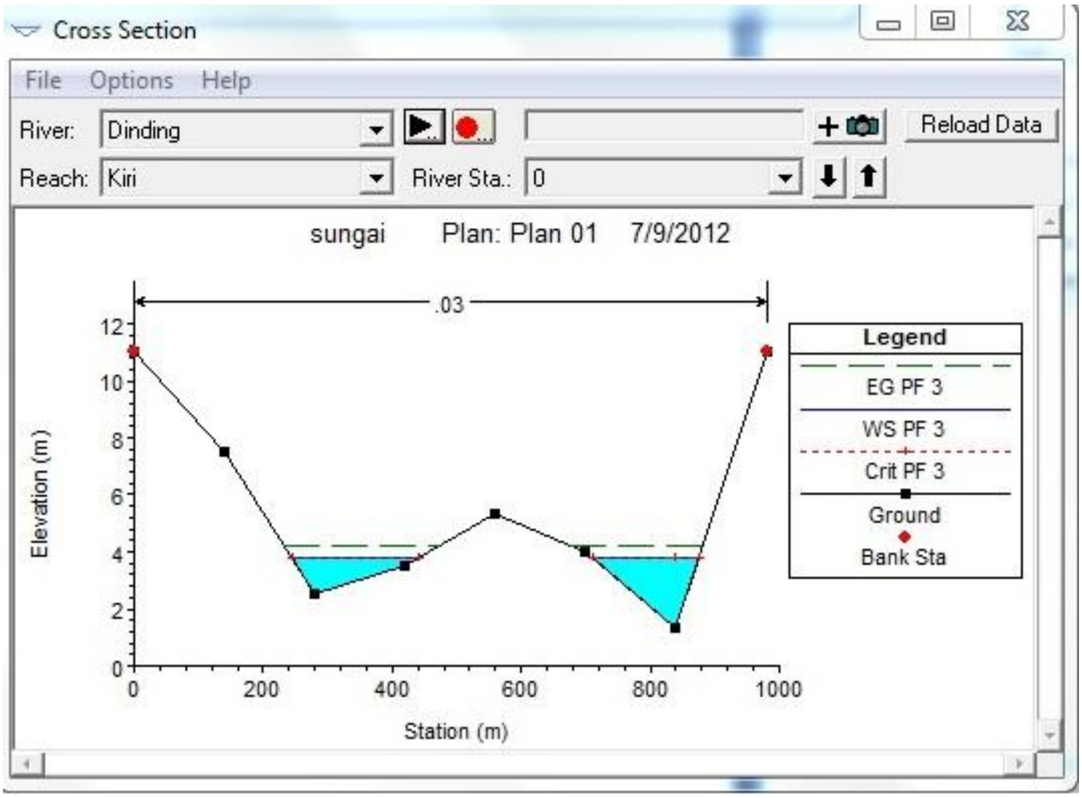
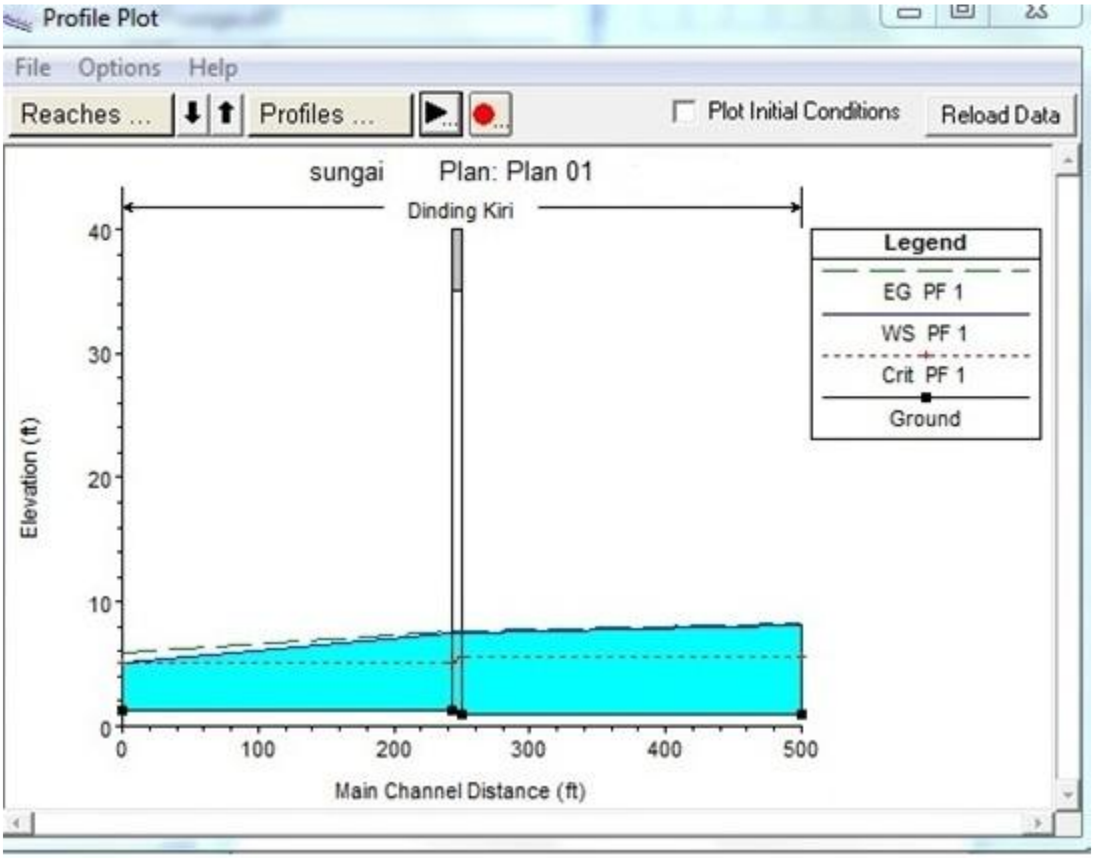


Figure 4.16: River cross section of Downstream



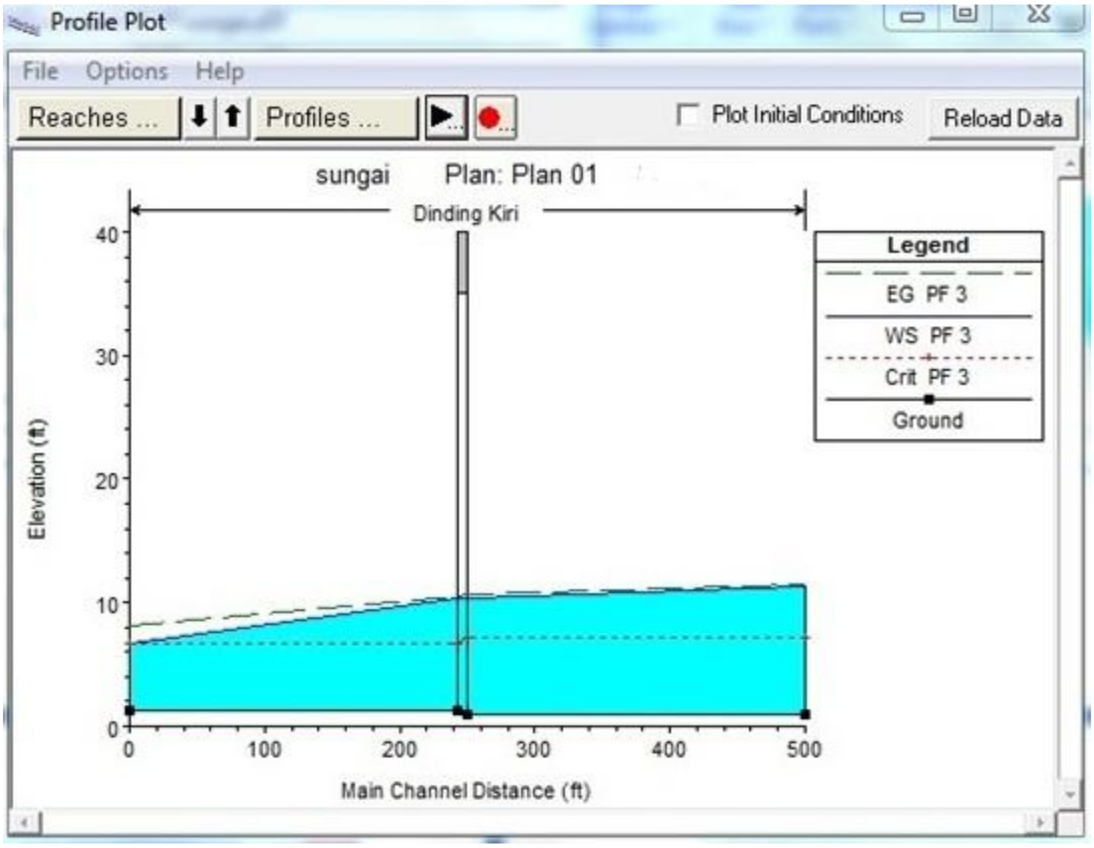


Figure 4.18: Output of Profile Plot

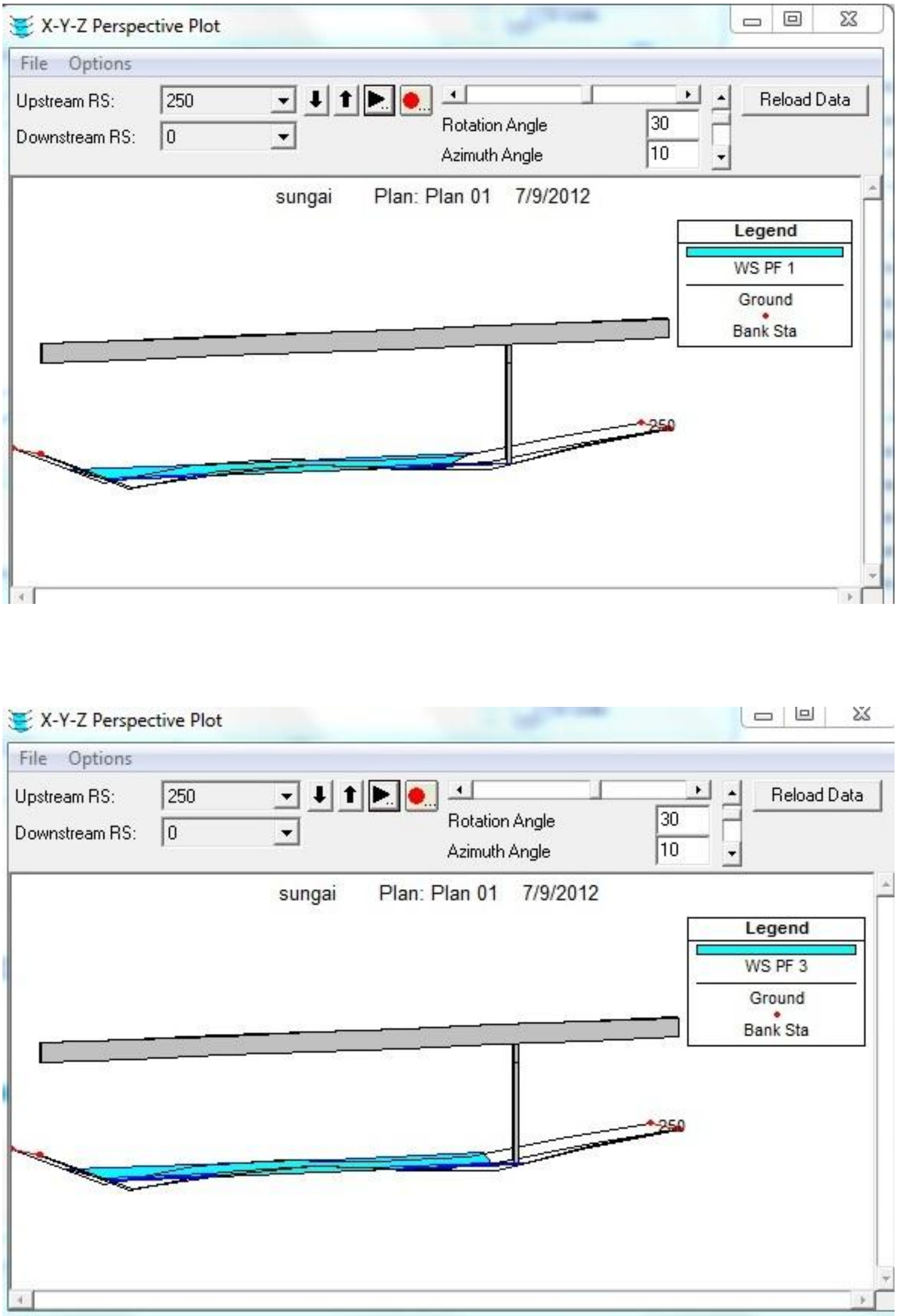


Figure 4.19: X-Y-Z Perspective Plot

As shown in the figures above, the cross section of river output were above the critical profile for both Profile 3 in the upstream and downstream. While in the upstream, the condition of water surface profile might be exceeding the river banks of the channel during the peak condition of the occurrences of both heavy rainfall and a very high tide.

Based from the analysis made using HEC-RAS, the flow of surface runoff might be overflow from the river into the river banks following the critical condition, which is in a high tide including the increased surface runoff produced by the rainfall occurrences.

There are points where runoff generated enters the network, but also the points where, in case of surcharge, water level may exceed ground elevation, and flow out of the network (flooding). High water tables in coastal areas generally are low-lying and thus vulnerable to flooding. High tides can decrease the elevation difference and further stopping the natural drainage. With water tables just below the land surface, a rainstorm can rapidly saturate the soil and increases runoff as the soil saturated.

System of drainage can be enhanced by using pipes or wider drainage channels. Communities with drainage systems in place can either install supplemental pipe systems or replace old pipes with larger ones. Locks and flap gates may provide a cost-effective interim solution for such area. During low tide, the gates could be open to permit release of runoff, while during high tides they could be closed to prevent runoff from coming up further inland.

Besides improving their drainage systems to prevent flooding, communities might choose to implement a combination of planning and structural measures to adapt to increase flooding. Buildings in low areas can be made flood proof, construction of basement can be avoided, and new buildings and streets to be constructed at higher elevations. The rural drainage has not been designed to manage an ARI of 100 and there will therefore need to be careful consideration of the increased risk imposed by the rural drainage overtopping.

4.3.1 HEC-RAS Study Limit Determination

During the process of performing the study, it is necessary to gather data from both upstream and downstream of study reach. Gathering of additional data in the upstream is necessary to evaluate the difference level of water for both during the respective condition of tidal ebbing and tidal flooding. A constraint of data causes the data Input of HEC-RAS was done in Steady Flow rather than Unsteady Flow, which is much more compatible to the condition of the flow in the study area.

In order to prevent any computed errors within the study reach, the unknown boundary condition should be placed far enough in the downstream such that the computed profile will converge to a consistent answer by the time the computations reach the downstream limit of the study.

To simulate the Unsteady Flow of HEC-RAS data, a much more variable of data needed in both upstream and downstream. For any continuous future undertakings on the project, it is necessary to collect data of the boundary conditions which consists of variable value of water characteristics to create an effective water surface profile.

Although the resultant HEC-RAS data simulation is different from the actual Unsteady Flow simulation, the Steady Flow simulation done could give an impression of rough analysis of the river channel’s movement along the tidal movement and peak discharge occurrences.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Floods are naturally caused by rainfall, but in urban areas it was characterized by inadequate adherence to planning regulations; even a short duration shower can be a critical initiator of flooding.

Floods cannot be prevented out rightly, but good planning and observance of the rules can reduce the level of vulnerability and facilitate coping. This calls for an integrated approach to urban flood management, since several element and dimension of urban planning can be identified. The unified urban flood management planning model must be developed for policy implementation. This implies that in considering options for flood mitigation or adaptation, all stakeholders, elements in flood management and dimensions of the society must be involved in flood management

As a conclusion, the peak condition of the combination of tidal flow and heavy rainfall will affect the drainage directly in the estuaries in many physical ways. From the past projects done by other people, there were so many impacts on the estuaries and their ecology based on many other causes. Going through this project, it is vital to find out the real impact it would have caused to the estuaries, and how.

Hydrologic and hydraulic model analysis carried out to investigate the hydraulic characteristic of channel that experiences flood problem due to rainfall and tidal influence. The current result shows that there is a very consistent movement of water getting in and out of the estuary.

As for any further research and work to be done in future, it is best to do the continuation of data collection and comparison with the existing data from other sources. The method can be extended and applied to similar drainage systems in coastal areas, and may turn useful during both the design and the operation and management phase. This will make the result to be much more reliable and can be used for further research and improvement.

CHAPTER 6

REFERENCES

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APPENDIX A

WATER ELEVATION DATA

WATER ELEVATION DATA (UPSTREAM)

PIER #1

	TRIP1						TRIP2						TRIP3						TRIP4								
Date:	9/3/12-11/3/12						27/4/12-19/4/12						26/5/12-28/5/12						29/6/12-1/7/12								
US/P1	Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3				
Time	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	**Max**	**Min**	**Mean**
6:00:00			3.582	3.262	4.117	4.36			3.843	3.242	3.645	3.242			4.008	3.683	3.835	3.47			2.375	1.955	2.71	2.447	4.36	1.955	3.361
10:00:00			3.163	5.795	2.18	2.064			3.569	3.014	3.753	3.689			3.168	4.211	3.509	3.087			4.084	3.348	2.693	1.919	5.795	1.919	3.327
14:00:00			2.609	2.471	1.928	1.269			2.702	1.764	2.822	2.544			2.189	1.765	2.497	2.005					3.881	2.902	3.881	1.764	2.382
18:00:00			4.457	3.975			3.755	3.399	3.272	3.093			3.944	3.256	3.621	3.176			2.03	1.952	2.324	2.05			4.457	1.952	3.164
22:00:00							3.202	2.635	3.176	3.365			3	2.844	3.496	2.951			3.222	2.956	2.785	2.324			3.496	2.324	2.247

PIER #2

	TRIP1						TRIP2						TRIP3						TRIP4								
Date:	9/3/12-11/3/12						27/4/12-19/4/12						26/5/12-28/5/12						29/6/12-1/7/12								
US/P1	Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3				
Time	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	**Max**	**Min**	**Mean**
6:00:00			7.64	7.405	8.203	7.724			7.718	5.394	7.599	6.543			8.227	7.743	8.017	7.483			6.629	5.832	6.704	5.973	8.227	5.394	7.177
10:00:00			6.173	6.146	6.271	6.045			7.556	7.85	7.615	6.45			7.514	6.332	7.77	6.879			9.923	7.293	6.916	4.797	9.923	4.797	6.970
14:00:00			6.252	3.674	6.094	5.406			6.868	5.236	7.097	6.066			6.582	5.918	6.688	6.033					8.023	6.768	8.023	3.674	6.193
18:00:00			8.611	2.992			7.998	7.377	7.572	6.471			7.754	4.794	7.995	6.734			6.227	5.723	6.454	5.977			8.611	2.992	6.619
22:00:00							7.412	5.804	7.402	6.843			7.185	6.79	7.492	6.183			7.312	6.539	6.838	6.337			7.492	5.804	6.844

PIER #3

	TRIP1						TRIP2						TRIP3						TRIP4								
Date:	9/3/12-11/3/12						27/4/12-19/4/12						26/5/12-28/5/12						29/6/12-1/7/12								
US/P1	Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3				
Time	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	**Max**	**Min**	**Mean**
6:00:00			8.28	7.895	8.875	7.15			7.276	6.09	8.193	6.984			8.803	8.329	7.152	7.221			7.209	6.196	7.348	6.858	8.875	6.09	7.491
10:00:00			6.556	4.808	6.844	4.188			8.252	6.451	8.292	7.552			7.846	6.643	8.392	6.242			8.293	7.918	7.87	6.295	8.392	4.188	7.027
14:00:00			6.924	6.579	8.628	5.789			7.529	5.492	7.786	6.498			7.295	6.453	7.433	6.615					8.773	8.059	8.773	5.789	7.132
18:00:00			9.256	3.786			8.641	8.084	8.299	7.696			8.706	5.679	7.885	6.914			6.95	6.742	7.178	6.605			8.706	3.786	7.315
22:00:00							7.978	6.839	8.069	6.872			7.765	6.829	8.009	7.135			7.936	7.671	7.408	6.589			8.069	6.589	7.425

PIER #4

	TRIP1						TRIP2						TRIP3						TRIP4								
Date:	9/3/12-11/3/12						27/4/12-19/4/12						26/5/12-28/5/12						29/6/12-1/7/12								
US/P1	Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3				
Time	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	**Max**	**Min**	**Mean**
6:00:00			6.47	6.164	7.099	6.294			6.683	5.598	6.343	5.654			7.048	6.606	6.946	6.484			5.391	4.89	5.375	4.642	7.099	4.642	6.105
10:00:00			5.138	4.996	4.972	4.866			6.385	4.708	6.434	6.143			6.182	5.582	6.505	5.577			6.301	6.073	5.837	4.789	6.505	4.708	5.655
14:00:00			5.256	5.103	5.036	4.452			5.633	4.587	5.927	5.31			5.52	4.516	5.598	4.932					6.952	6.137	6.952	4.452	5.354
18:00:00			7.709	4.99			6.881	5.872	6.463	5.794			7.001	6.41	6.84	5.994			5.158	4.104	5.294	4.738			7.709	4.104	5.946
22:00:00							6.17	5.062	6.266	5.47			5.993	5.524	6.319	5.831			6.155	5.679	5.64	5.218			6.319	5.062	5.777

PIER #5

	TRIP1						TRIP2						TRIP3						TRIP4								
Date:	9/3/12-11/3/12						27/4/12-19/4/12						26/5/12-28/5/12						29/6/12-1/7/12								
US/P1	Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3				
Time	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	**Max**	**Min**	**Mean**
6:00:00			7.015	6.784	7.587	6.871			7.034	5.828	6.909	6.014			7.524	6.78	7.432	6.698			5.921	5.504	6.079	5.615	7.587	5.504	6.599
10:00:00			5.261	7.19	5.563	5.442			6.912	4.701	7.048	6			6.876	5.973	7.127	6.604			7.458	4.947	6.552	6	7.458	4.701	6.254
14:00:00			5.546	4.893	5.344	4.78			6.217	5.215	6.476	6.371			6.132	5.279	6.132	5.468					7.539	6.869	7.539	4.78	5.875
18:00:00			7.918	5.305			7.286	6.148	6.926	6.692			5.854	6.887	7.326	6.534			5.807	5.037	5.895	5.323			7.918	5.037	6.352
22:00:00							6.626	5.947	6.813	6.254			6.545	5.652	6.892	6.451			6.687	5.959	6.099	5.737			6.892	5.652	6.305

PIER #6

	TRIP1						TRIP2						TRIP3						TRIP4								
Date:	9/3/12-11/3/12						27/4/12-19/4/12						26/5/12-28/5/12						29/6/12-1/7/12								
US/P1	Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3				
Time	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	**Max**	**Min**	**Mean**
6:00:00			9.21	8.663	12.455	8.631			11.698	10.569	12.554	11.306			11.527	11.67	8.792	11.255			11.484	10.686	11.209	10.015	12.554	8.631	10.732
10:00:00			7.366	7.707	8.48	8.534			12.315	7.74	11.775	11.129			10.594	11.432	7.568	9.874			9.516	10.028	11.813	10.204	12.315	7.707	9.754
14:00:00			7.553	7.398	8.536	8.022			11.28	9.989	12.36	11.656			9.412	10.319	8.363	9.927					10.577	11.096	12.36	7.398	9.749
18:00:00			11.044	8.888			11.862	9.029	11.29	10.974			10.13	10.466	9.533	11.596			10.14	9.53	11.162	10.041			11.862	8.888	10.406
22:00:00							11.234	5.109	12.51	10.755			10.419	11.231	9.665	10.936			11.501	10.821	10.541	8.964			11.501	5.109	10.307

WATER ELEVATION DATA (DOWNSTREAM)

PIER #1

	TRIP1						**TRIP2**						**TRIP3**						**TRIP4**								
Date:	9/3/12-11/3/12						27/4/12-19/4/12						26/5/12-28/5/12						29/6/12-1/7/12								
US/P1	Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3				
Time	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	**Max**	**Min**	**Mean**
6:00:00			5.1		4.212	4.173			4.161	3.408	3.736	3.196			4.333	3.78	4.52	3.689			2.951	2.392	2.783	2.392	5.1	2.392	3.655
10:00:00			1.927	1.653	2.233	2.275			3.622	2.688	3.756	3.904			3.571	3.215	3.885	3.254			3.55	3.729	3.311	2.767	3.885	1.653	3.083
14:00:00			2.551	2.489	2.319	1.972			3.197	2.42	3.289	3.347			3.033	2.32	3.256	2.592					4.45	3.94	4.45	1.972	3.167
18:00:00			4.735	4.657			4.216	3.506	3.837	3.591			4.555	4.15	4.597	3.715			2.673	2.349	4.542	3.116			4.597	2.349	3.874
22:00:00							4.28	4.374	3.693	3.494			3.205	2.813	3.9	3.229			3.4	2.813	3.549	3.035			4.374	2.813	3.482

PIER #2

	TRIP1						**TRIP2**						**TRIP3**						**TRIP4**								
Date:	9/3/12-11/3/12						27/4/12-19/4/12						26/5/12-28/5/12						29/6/12-1/7/12								
US/P1	Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3				
Time	US 1	US 2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	**Max**	**Min**	**Mea n**
6:00:00			10	10.1	11.32 2	9.15 9			10.00 8	8.79 1	10.07 4	8.42 3			10.67	10.78 7	7.407	9.409			6.75 6	5.94 7	6.67 1	6.33 2	11.32 2	5.94 7	9.457
10:00:00			9.00 2	9.28 4	8.349	9.06 3			8.711	7.22 3	8.218	8.16 8			8.622	7.885	11.13 5	10.74 6			7.69 3	8.08 9	7.70 4	7.50 8	11.13 5	7.22 3	8.588
14:00:00			8.04 9	8.62 2	7.697	6.42 5			7.472	2.41	7.856	8.24 9			8.606	6.695	9.867	7.314					4.25	8.38 5	9.867	2.41	7.278
18:00:00			8.52 4	6.57 4			8.64 1	5.78 8	8.723	7.89 5			8.62 4	11.46 1	9.138	8.281			11	10.46 8	8.65 3	8			11.46 1	5.78 8	8.668
22:00:00							7.00 1	5.17 9	8.043	7.67 2			9.46	8.82	10.32 7	10.27 5			7.96 6	7.381	9.14 8	8.31 2			10.32 7	5.17 9	8.299

PIER #3

	TRIP1						TRIP2						TRIP3						TRIP4								
Date:	9/3/12-11/3/12						27/4/12-19/4/12						26/5/12-28/5/12						29/6/12-1/7/12								
US/P1	Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3				
Time	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	**Max**	**Min**	**Mean**
6:00:00			9.08	8.43	8.708	8.566			8.353	7.152	8.175	7.825			8.696	8.222	8.586	6.989			7.126	6.703	7.384	6.934	9.08	6.703	8.462
10:00:00			7.128	6.782	6.704	6.576			8.123	7.286	8.185	7.632			8.07	7.487	8.356	7.571			7.251	7.326	8.028	7.051	8.356	6.576	7.472
14:00:00			6.953	6.687	6.659	6.182			7.47	2.39	7.672	7.745			7.26	6.373	7.327	6.605					8.6	7.765	8.6	2.39	6.835
18:00:00			9.414	8.523			8.622	6.54	8.225	7.645			8.75	8.461	8.598	8.063			6.976	6.407	7.084	6.552			9.414	6.407	7.847
22:00:00							7.303	6.187	7.973	7.573			7.642	7.394	7.981	7.519			7.868	7.16	7.345	6.938			7.981	6.187	7.407

PIER #4

	TRIP1						TRIP2						TRIP3						TRIP4								
Date:	9/3/12-11/3/12						27/4/12-19/4/12						26/5/12-28/5/12						29/6/12-1/7/12								
US/P1	Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3				
Time	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	**Max**	**Min**	**Mean**
6:00:00			7.041	6.843	6.673	6.592			6.339	4.955	6.179	5.696			6.755	5.685	6.652	6.07			5.054	4.593	5.373	4.977	7.041	4.977	6.365
10:00:00			5.265	4.891	4.731	4.723			6.07	5.354	6.163	5.919			5.994	5.294	6.313	5.579			6.629	5.838	5.902	5.023	6.629	4.731	5.606
14:00:00			4.985	4.848	4.658	4.296			5.336	2.38	5.68	5.665			5.261	4.342	5.339	4.381					6.613	5.971	6.613	2.38	4.983
18:00:00			7.137	7.134			6.531	5.657	6.194	4.287			6.726	6.125	6.554	5.907			4.985	4.632	5.022	4.483			7.137	4.287	5.812
22:00:00							5.331	4.505	5.936	6.066			5.616	5.275	5.977	5.572			8.892	5.379	5.365	4.964			8.892	4.505	5.74

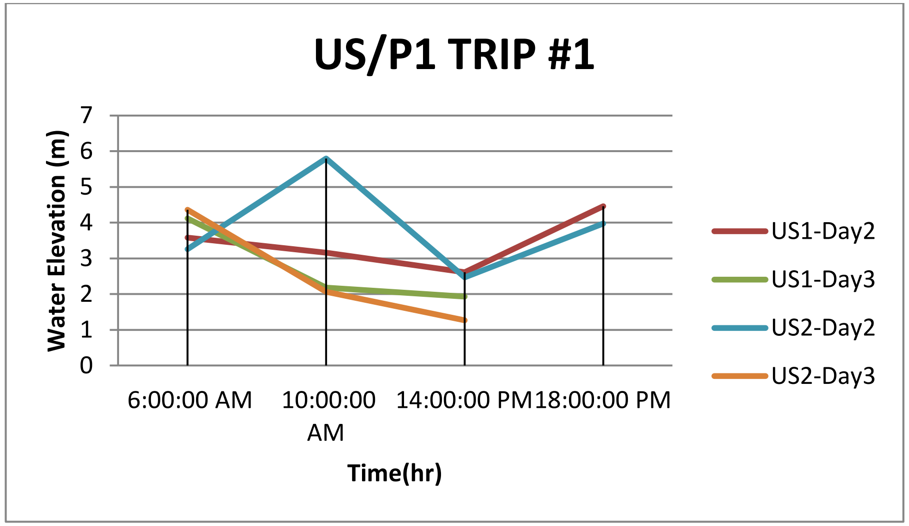
PIER #5

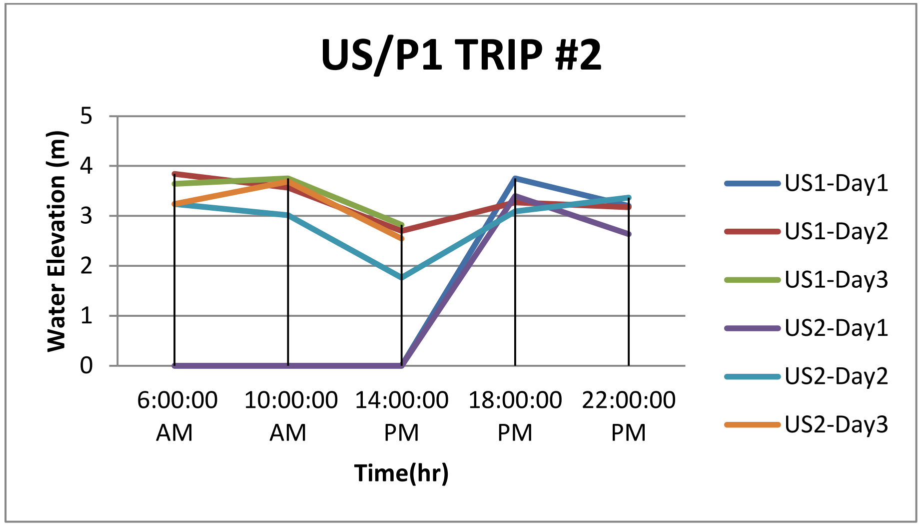
	TRIP1						TRIP2						TRIP3						TRIP4								
Date:	9/3/12-11/3/12						27/4/12-19/4/12						26/5/12-28/5/12						29/6/12-1/7/12								
US/P1	Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3				
Time	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	**Max**	**Min**	**Mean**
6:00:00			7	7.198	8.217	7.905			8.341	6.905	7.583	6.868			8.124	7.554	7.85	7.232			6.771	6.732	6.116	5.669	8.341	5.669	7.769
10:00:00			5.403	5.151	6.656	6.25			8.058	6.611	8	7.897			7.844	7.521	8	6.737			7.141	6.94	7	5.607	8.058	5.151	6.895
14:00:00			6.223	5.958	5.846	5.321			6.888	2.35	6.841	6.343			6.426	5.625	6.748	6.148					7.657	6.729	7.657	2.35	6.078
18:00:00			11.14	5.936			9.642	7.25	7.602	7.219			8.141	7.729	7.685	7.101			5.993	5.587	6.902	6.251			9.642	5.587	7.441
22:00:00							6.465	5.532	7.745	7.782			6.78	6.503	7.55	5.574			7.263	6.555	6.514	6.104			7.782	5.532	6.697

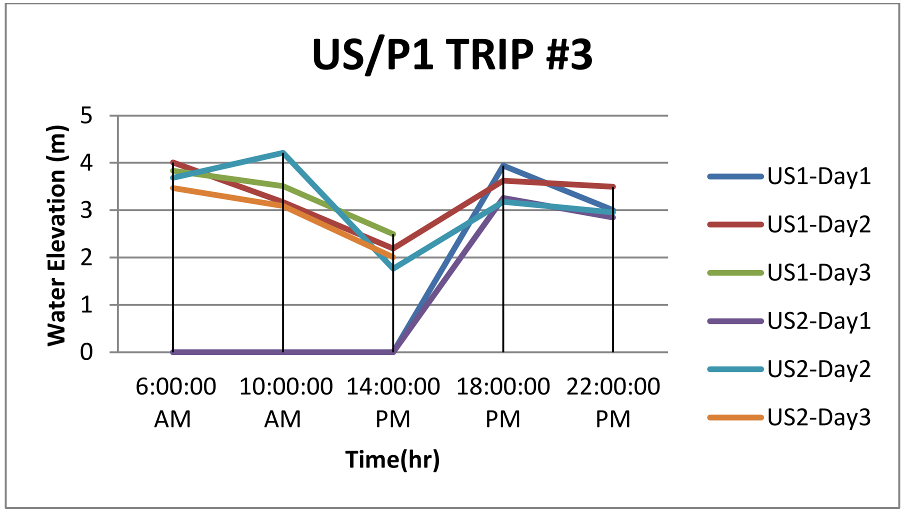
PIER #6

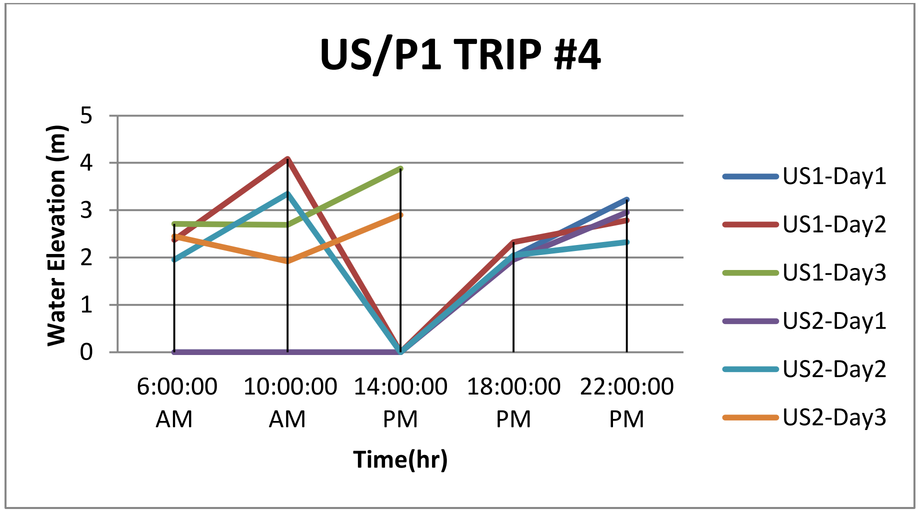
	TRIP1						TRIP2						TRIP3						TRIP4								
Date:	9/3/12-11/3/12						27/4/12-19/4/12						26/5/12-28/5/12						29/6/12-1/7/12								
US/P1	Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3		Day1		Day2		Day3				
Time	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	US1	US2	**Max**	**Min**	**Mean**
6:00:00			13.86	12.889	10.701	9.245			10.63	8.971	10.673	9.971			11.231	10.236	6.846	10.351			8.985	8.557	10.582	9.763	13.86	6.846	10.899
10:00:00			10.67	7.623	9.893	9.437			10.377	8.345	10.27	10.027			10.717	9.63	10.41	9.496			7.96	9.158	11.241	9.47	11.241	7.96	9.670
14:00:00			9.666	3.967	9.462	7.798			9.917	2.34	9.996	9.54			9.568	7.929	9.245	8.333					10.638	9.589	10.638	2.34	8.427
18:00:00			11.705	8.905			11.014	9.266	10.769	9.972			11.221	10.589	10.97	10.482			9.903	8.42	9.285	8.466			11.705	8.42	10.069
22:00:00							10.001	9.021	9.809	9.455			10.067	9.433	8.562	8.739			10.23	9.639	9.584	8.754			10.23	8.562	9.441

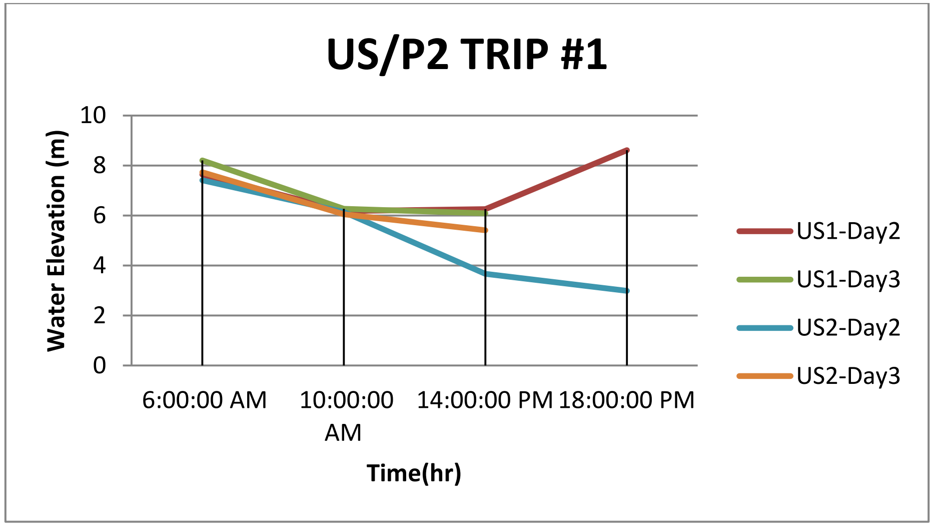
GRAPHS OF WATER ELEVATION VS TIME (UPSTREAM)

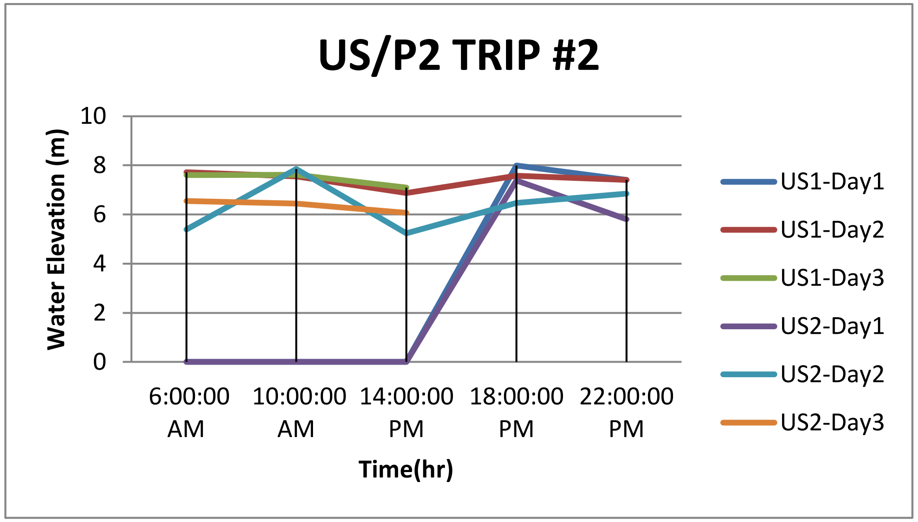


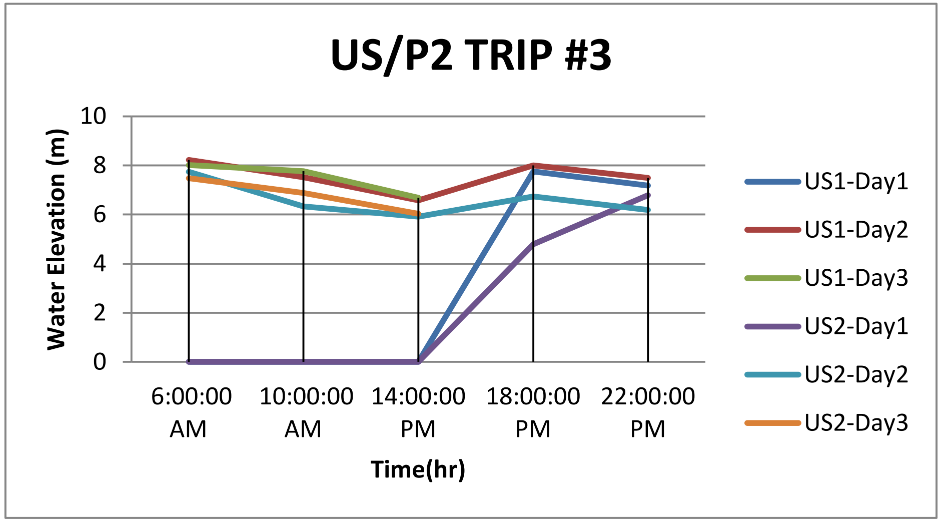







US/P2 TRIP #1
Water Elevation (m)
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
US1-Day2
US1-Day3
US2-Day2
US2-Day3


US/P2 TRIP #2
Water Elevation (m)
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3


US/P2 TRIP #3
Water Elevation (m)
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
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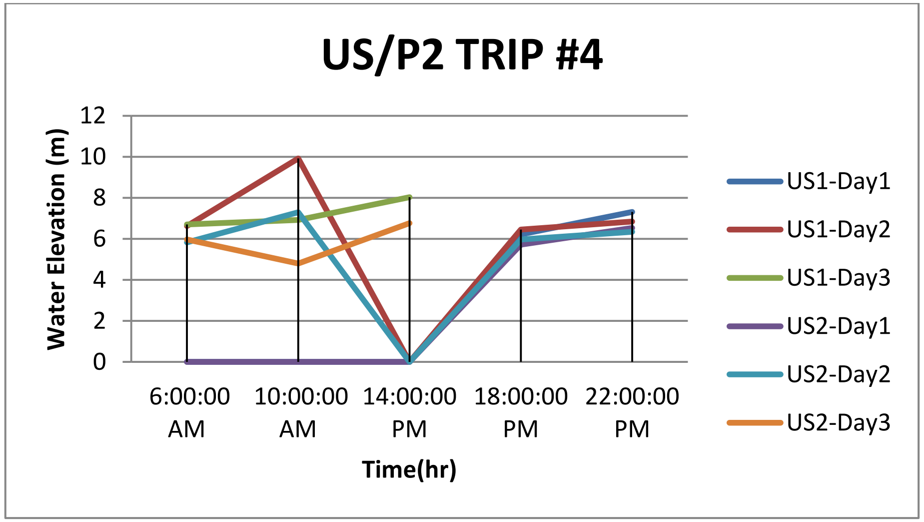
US2-Day2
US2-Day3


US/P2 TRIP #4
Water Elevation (m)
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10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
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Time(hr)
US1-Day1
US1-Day2
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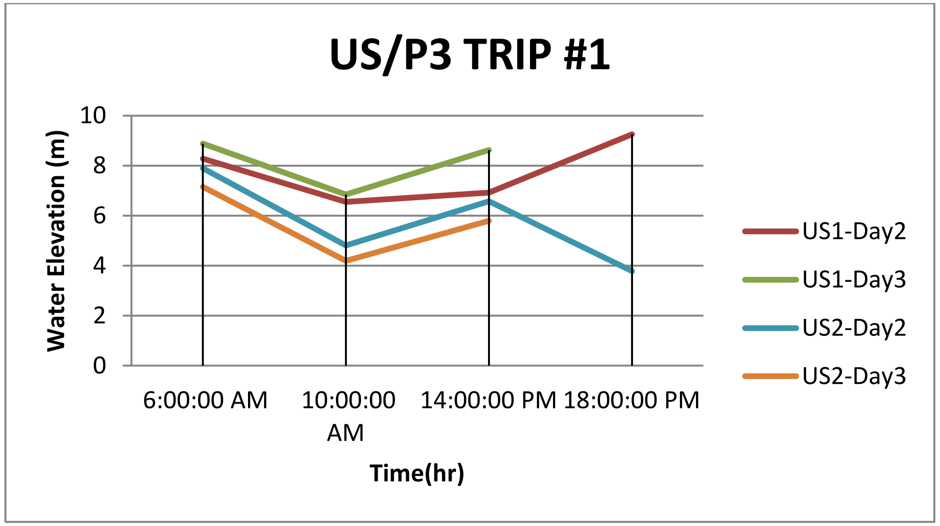
US2-Day1
US2-Day2
US2-Day3


US/P3 TRIP #1
Water Elevation (m)
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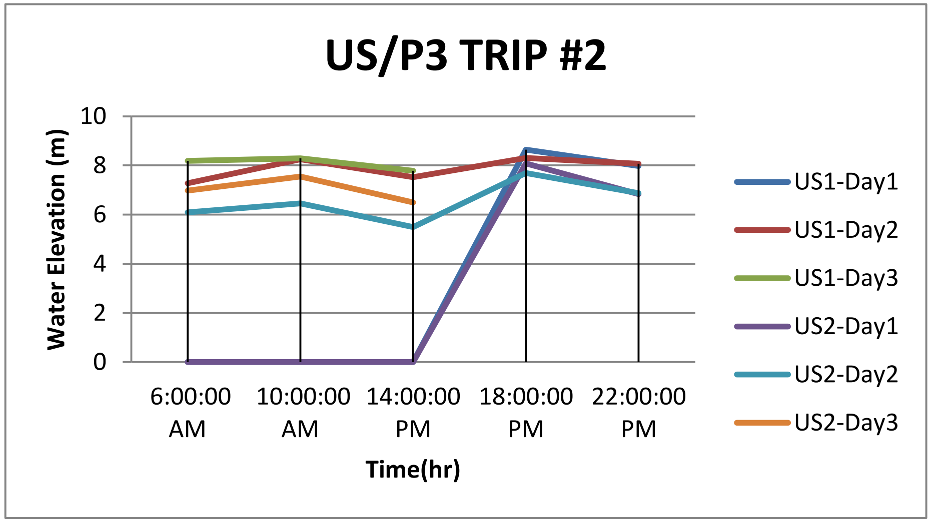
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
US1-Day2
US1-Day3
US2-Day2
US2-Day3


US/P3 TRIP #2
Water Elevation (m)
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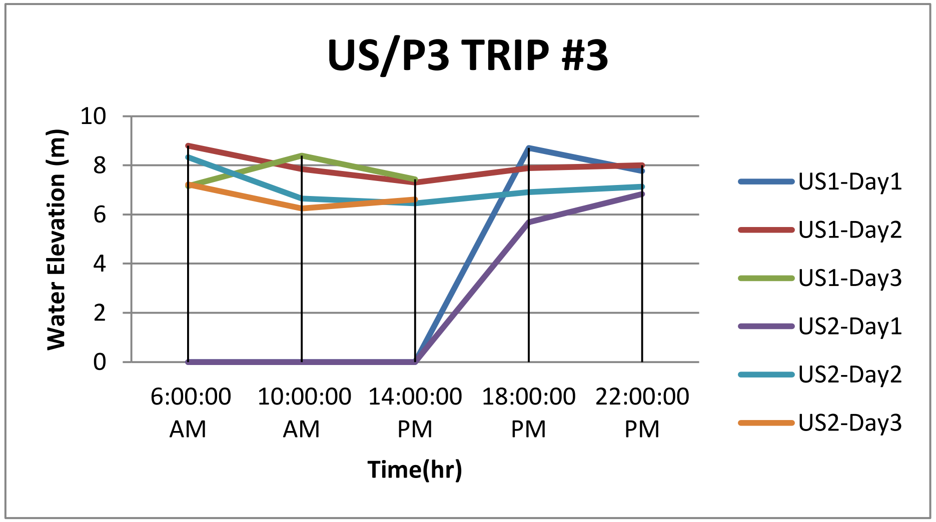
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3


US/P3 TRIP #3
Water Elevation (m)
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8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
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Time(hr)
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US1-Day2
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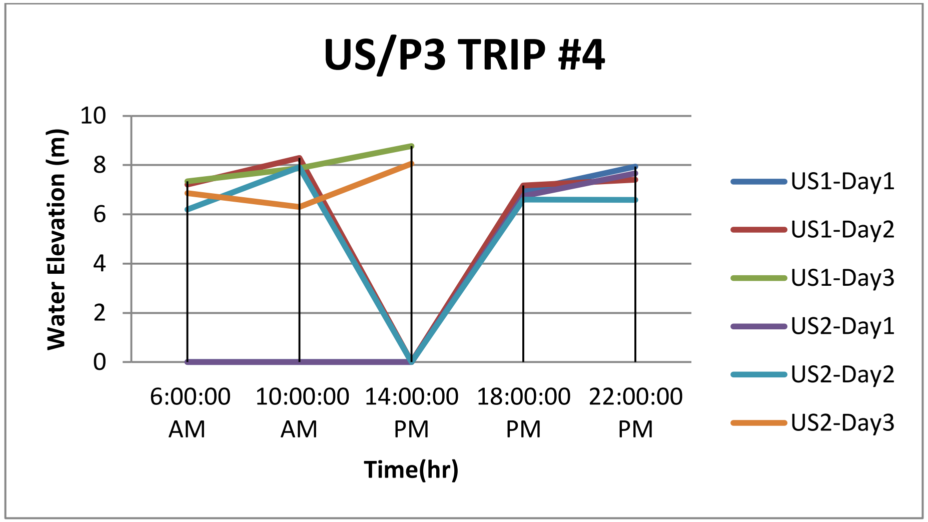
US2-Day2
US2-Day3


US/P3 TRIP #4
Water Elevation (m)
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8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
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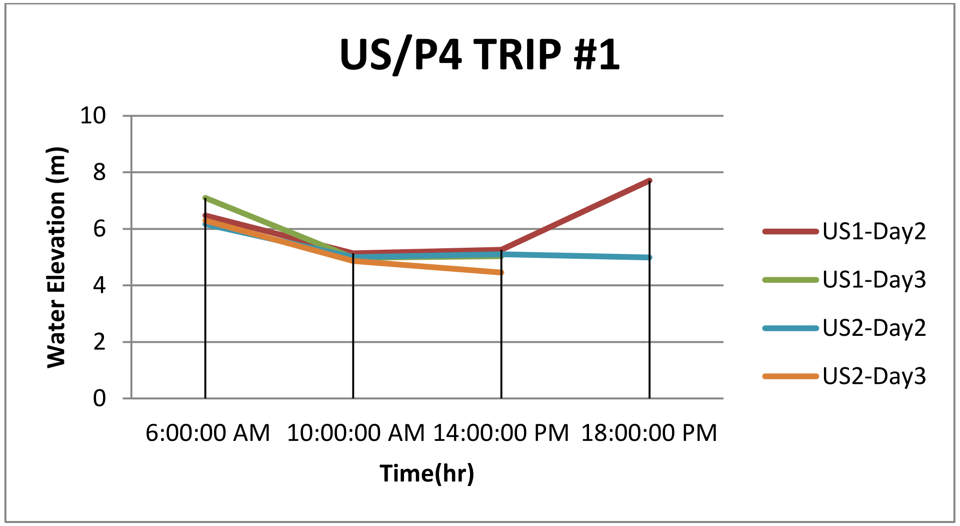
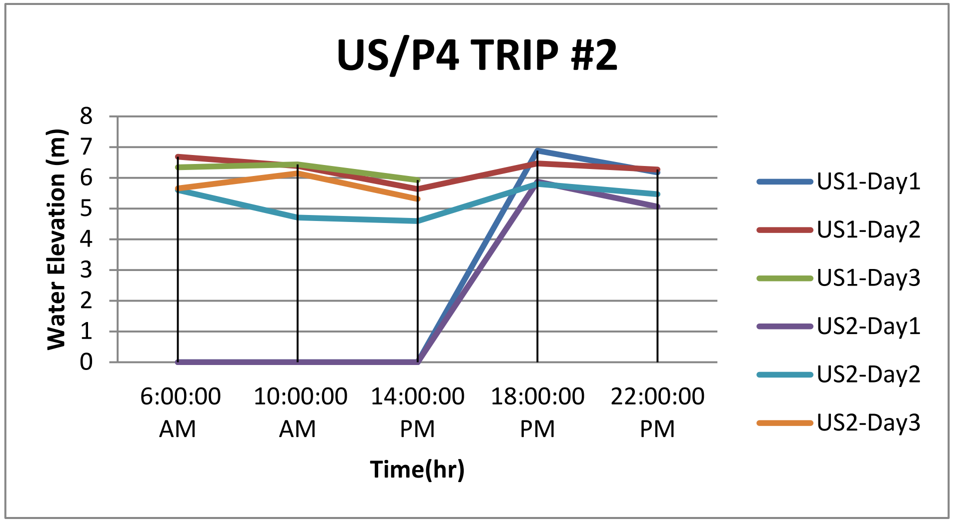
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3


US/P4 TRIP #1
Water Elevation (m)
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
US1-Day2
US1-Day3
US2-Day2
US2-Day3


US/P4 TRIP #2
Water Elevation (m)
8
7
6
5
4
3
2
1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
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Time(hr)
US1-Day1
US1-Day2
US1-Day3
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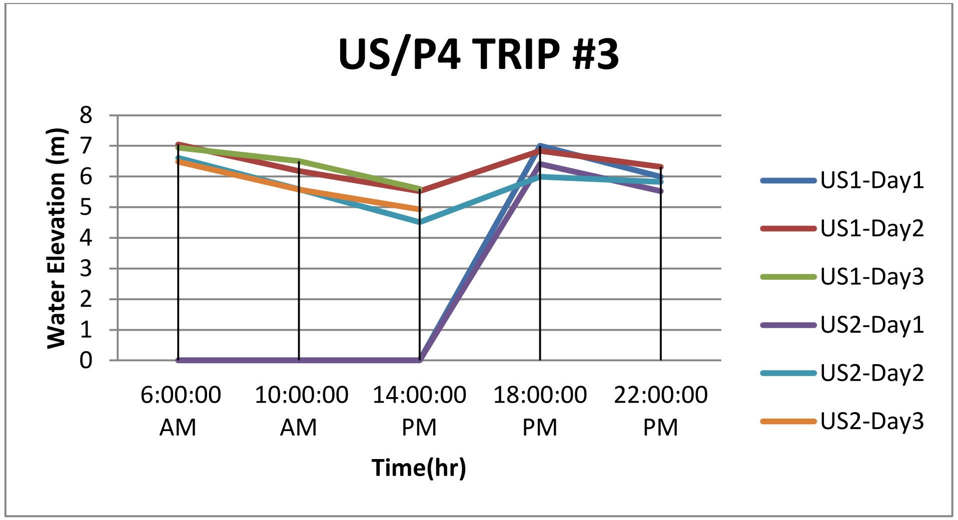
US2-Day2
US2-Day3


US/P4 TRIP #3
Water Elevation (m)
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7
6
5
4
3
2
1
0
6:00:00 AM
10:00:00 AM
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Time(hr)
US1-Day1
US1-Day2
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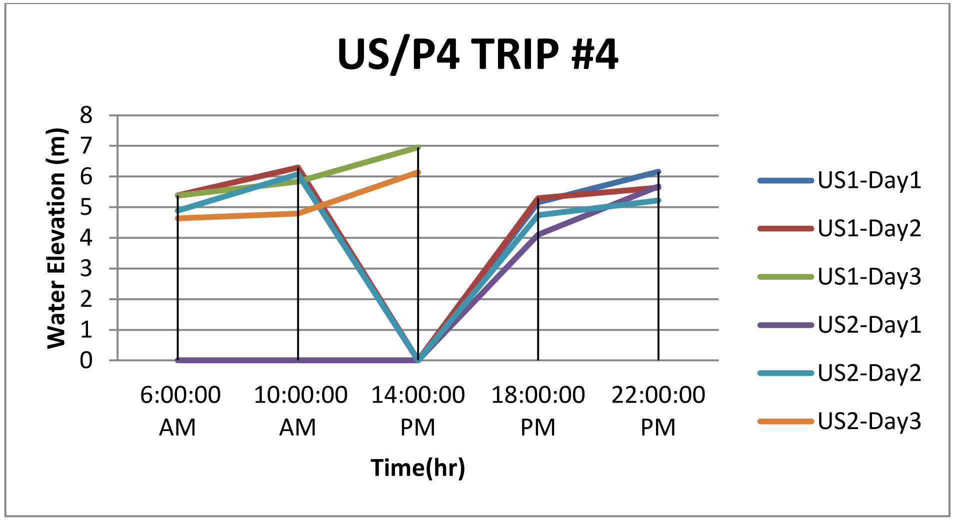
US2-Day2
US2-Day3


US/P4 TRIP #4
Water Elevation (m)
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7
6
5
4
3
2
1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
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Time(hr)
US1-Day1
US1-Day2
US1-Day3
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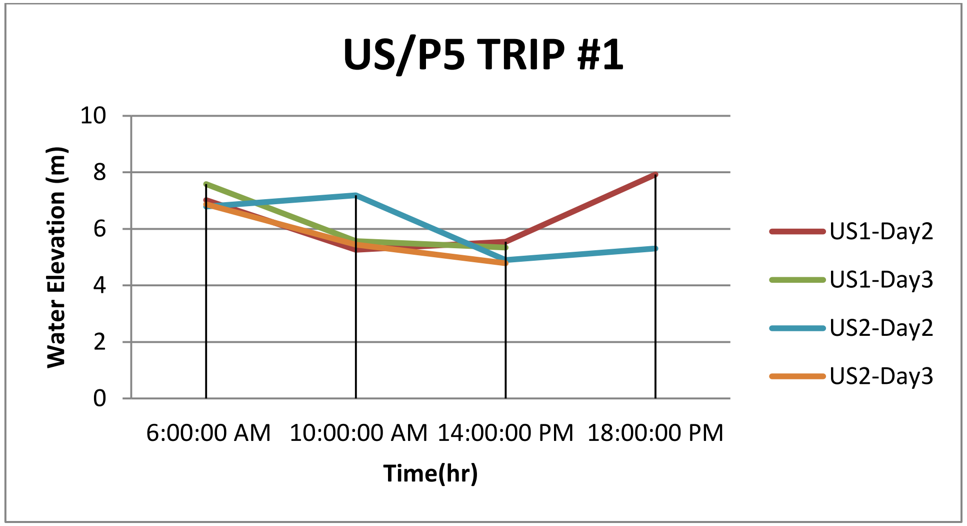
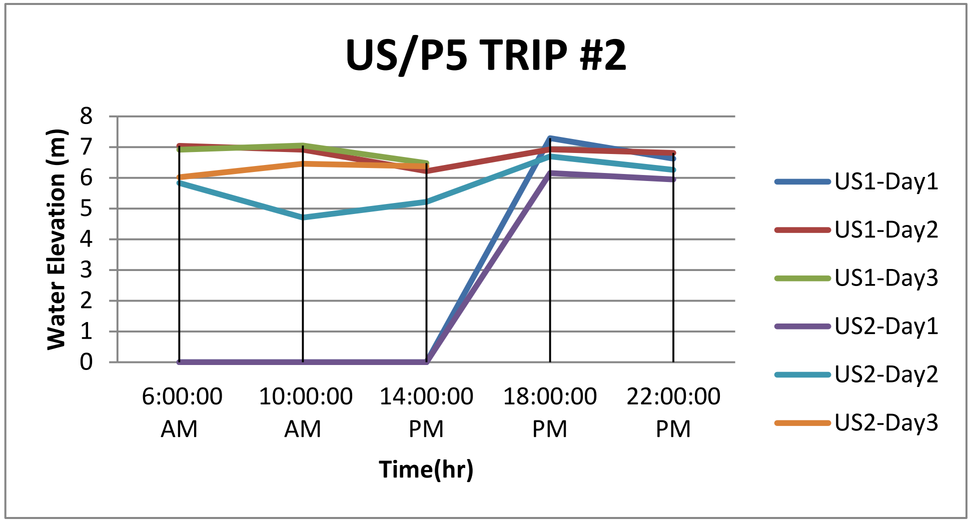
US2-Day2
US2-Day3


US/P5 TRIP #1
Water Elevation (m)
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
US1-Day2
US1-Day3
US2-Day2
US2-Day3


US/P5 TRIP #2
Water Elevation (m)
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7
6
5
4
3
2
1
0
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10:00:00 AM
14:00:00 PM
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Time(hr)
US1-Day1
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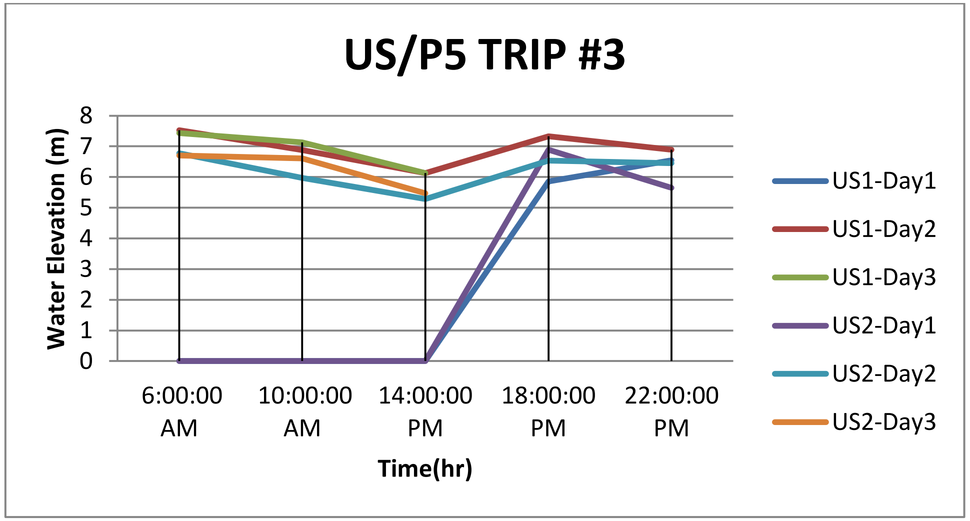
US2-Day2
US2-Day3


US/P5 TRIP #3
Water Elevation (m)
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7
6
5
4
3
2
1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
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Time(hr)
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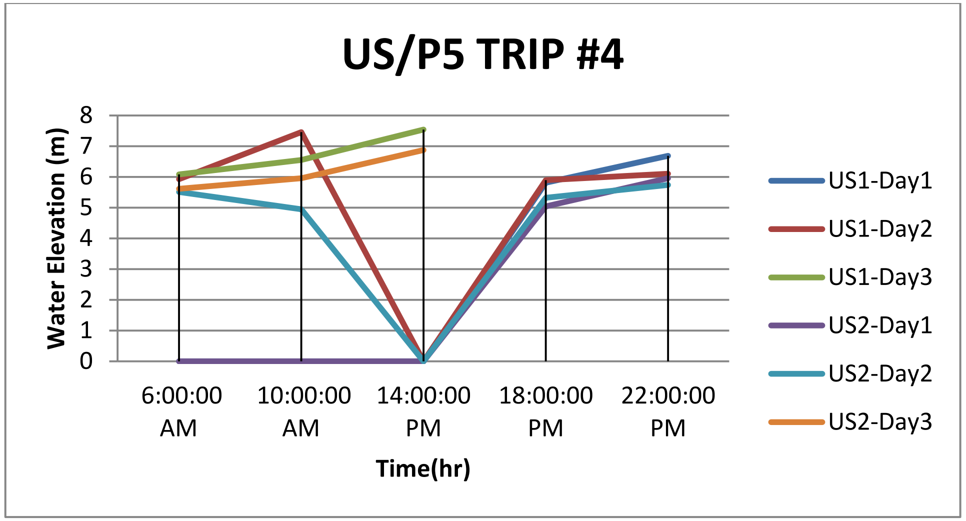
US2-Day2
US2-Day3


US/P5 TRIP #4
Water Elevation (m)
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7
6
5
4
3
2
1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
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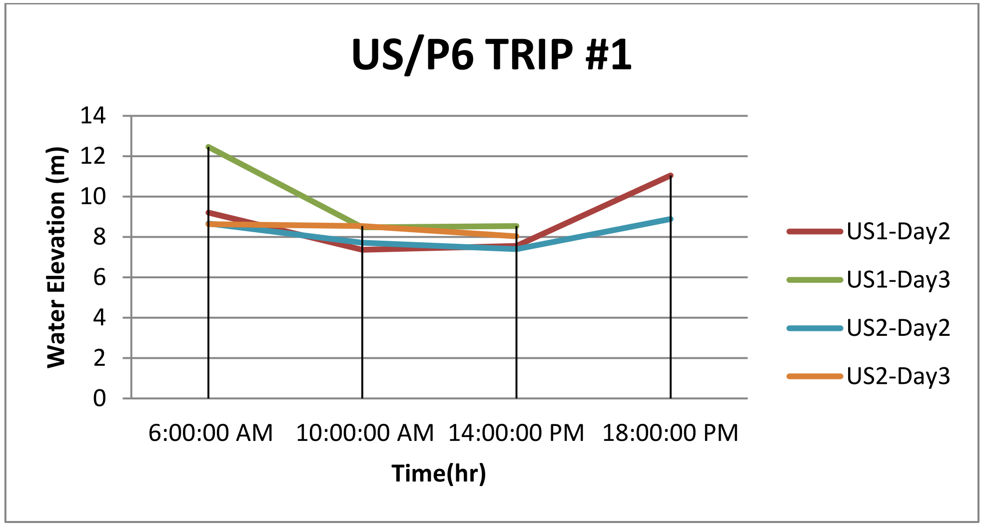
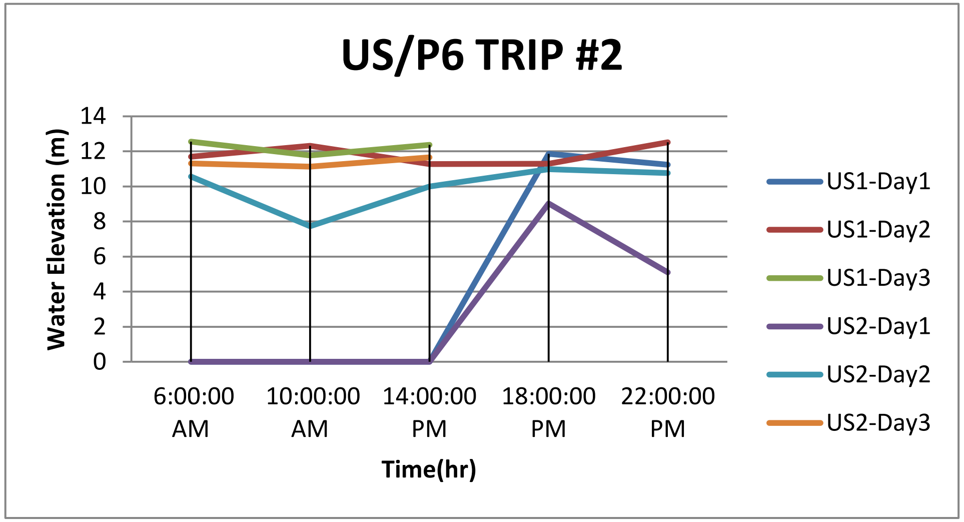
US2-Day2
US2-Day3


US/P6 TRIP #1
Water Elevation (m)
14
12
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
US1-Day2
US1-Day3
US2-Day2
US2-Day3


US/P6 TRIP #2
Water Elevation (m)
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12
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
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18:00:00 PM
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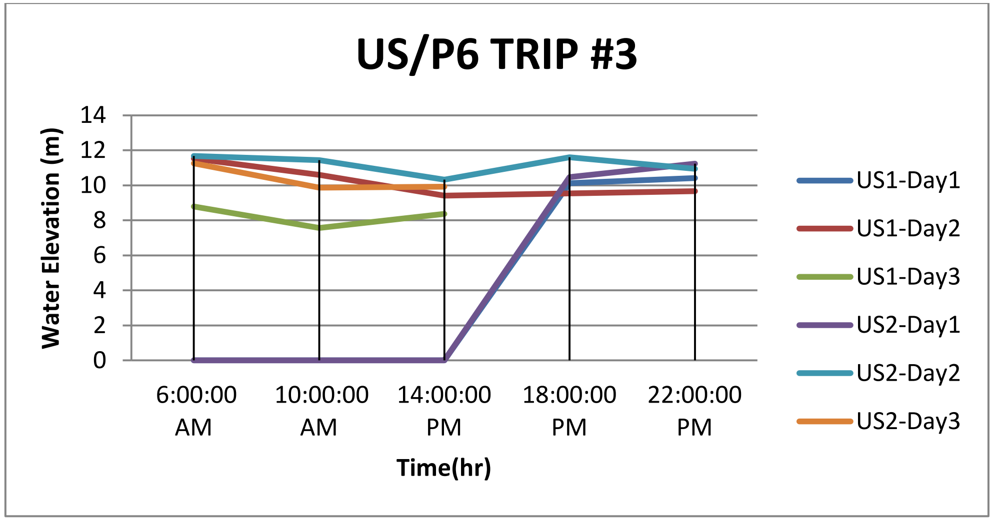
US2-Day2
US2-Day3


US/P6 TRIP #3
Water Elevation (m)
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12
10
8
6
4
2
0
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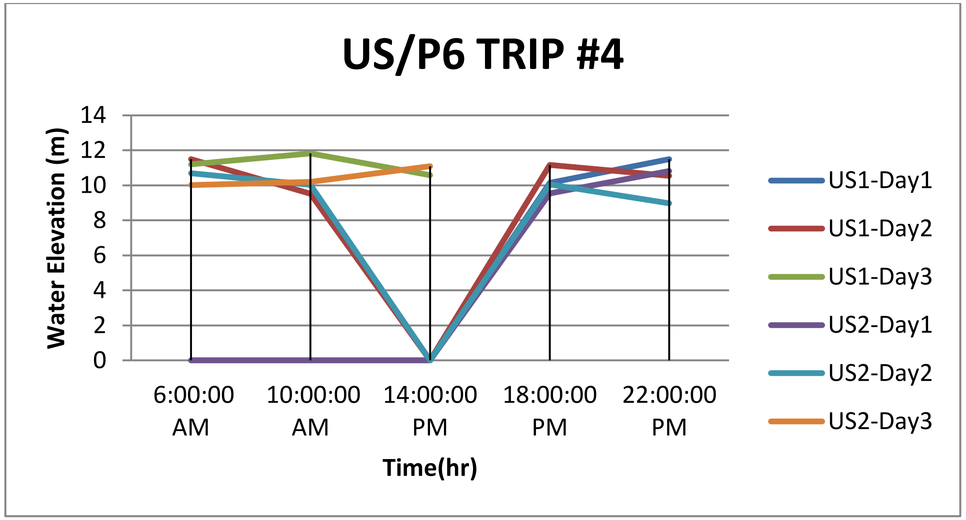
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3


US/P6 TRIP #4
Water Elevation (m)
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10
8
6
4
2
0
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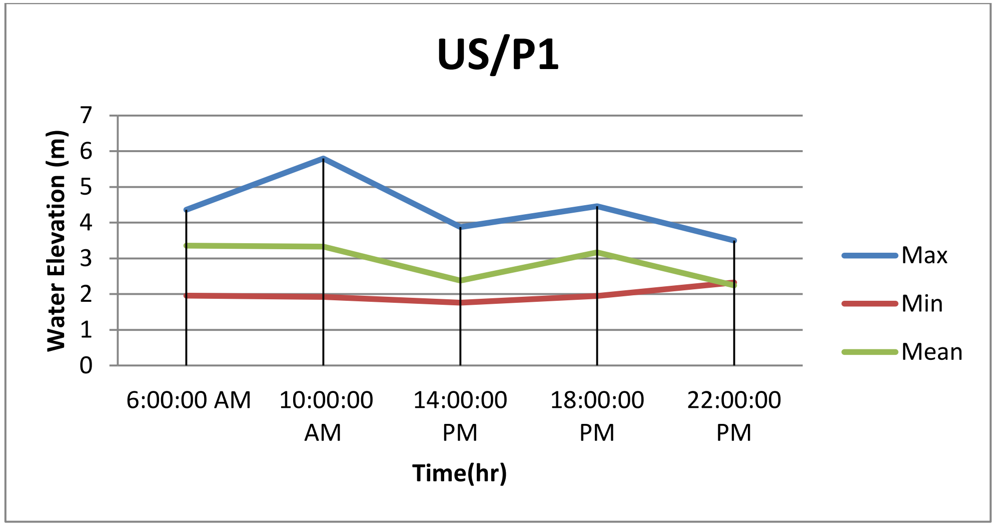
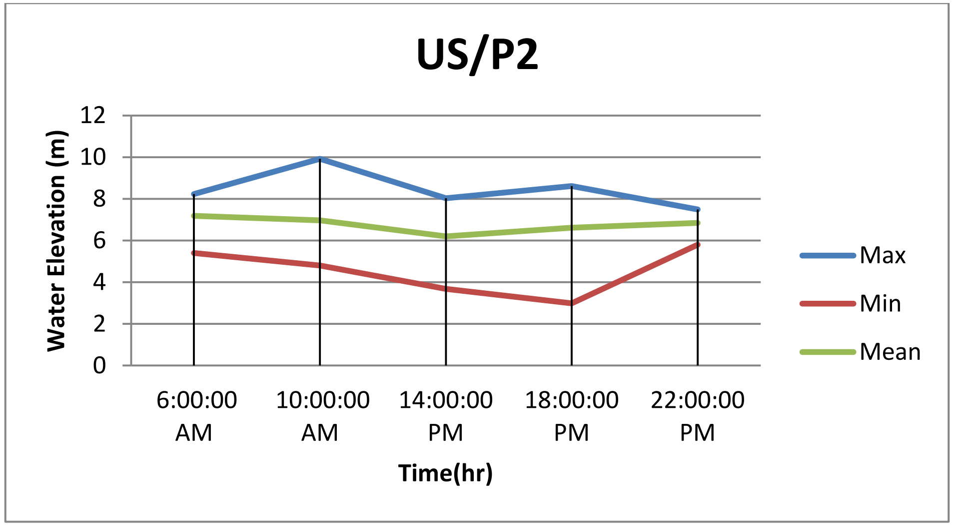
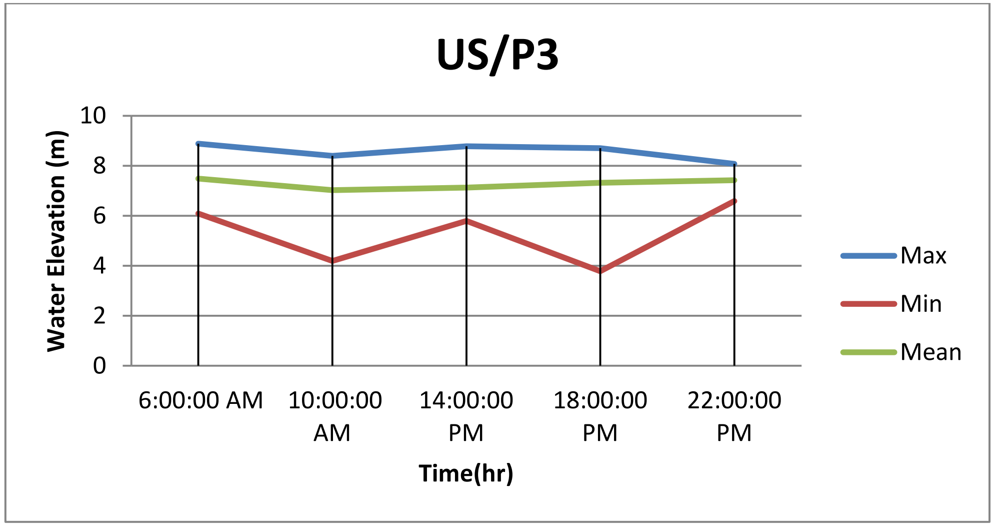
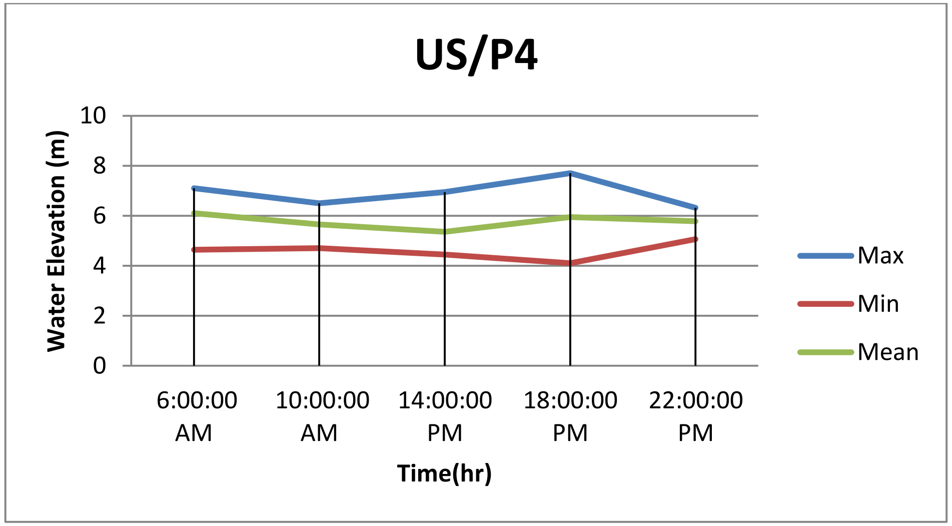
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3

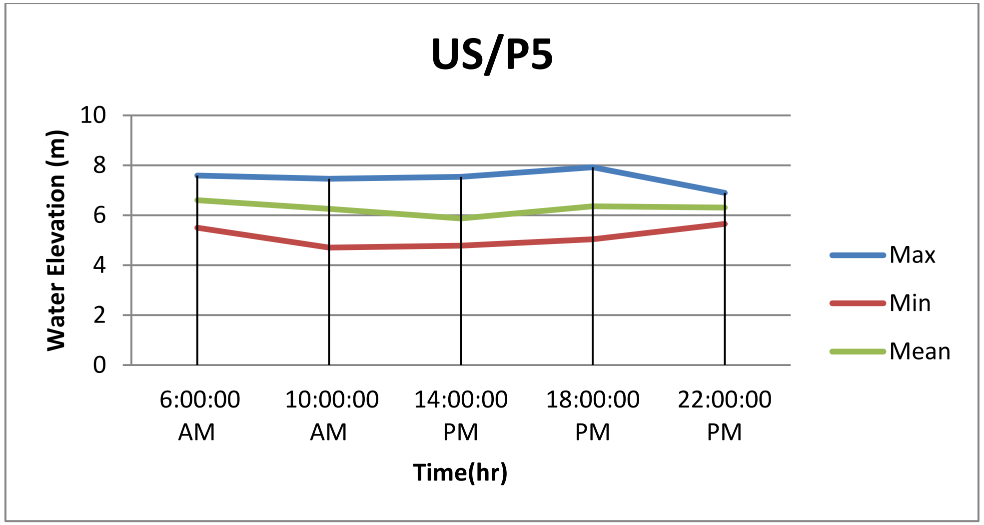
GRAPHS OF MAXIMUM, MINIMUM AND AVERAGE WATER ELEVATION VS TIME (UPSTREAM)

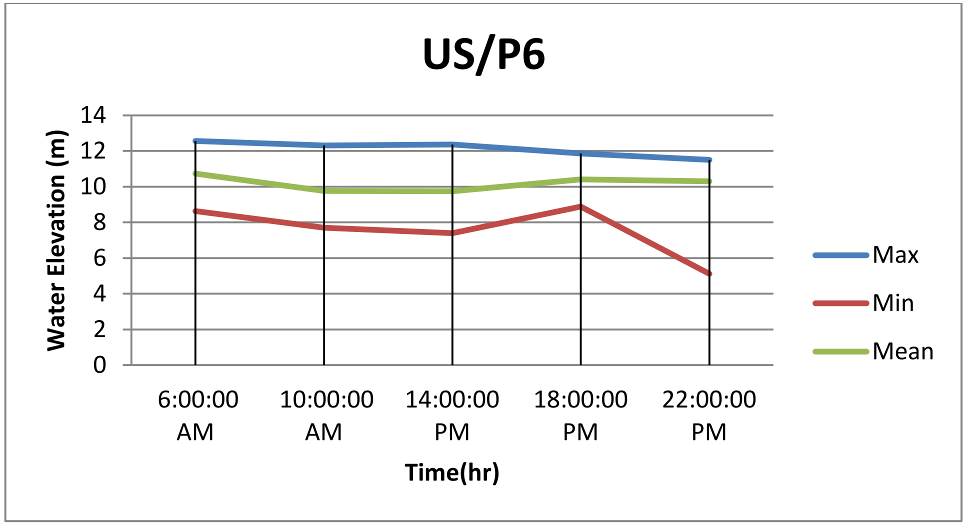




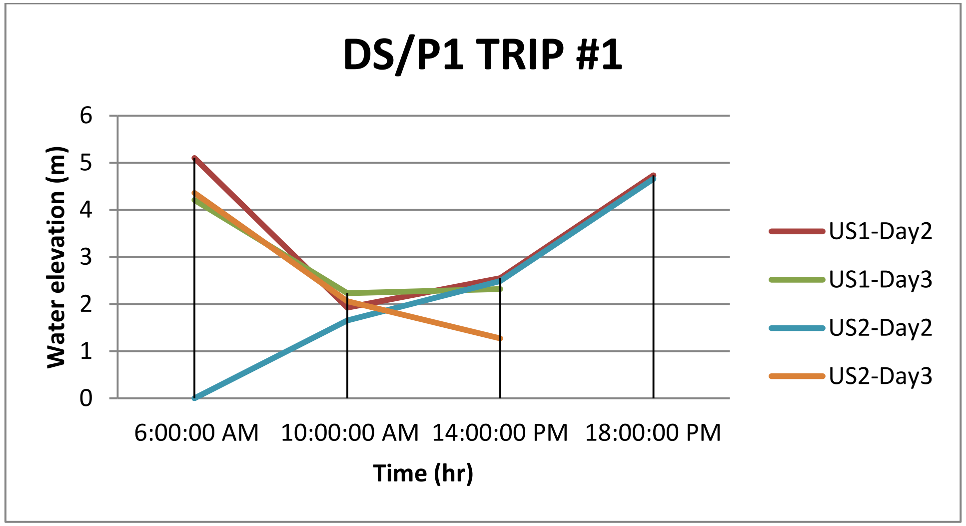


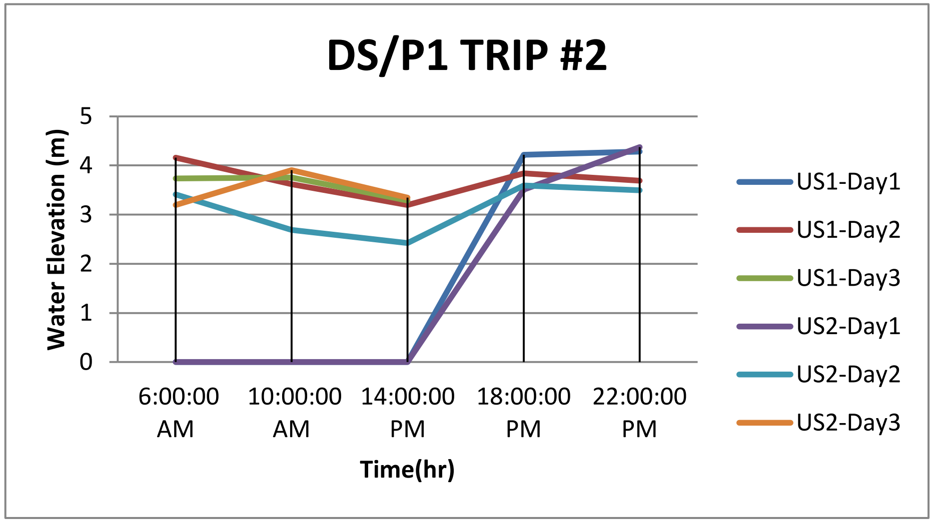


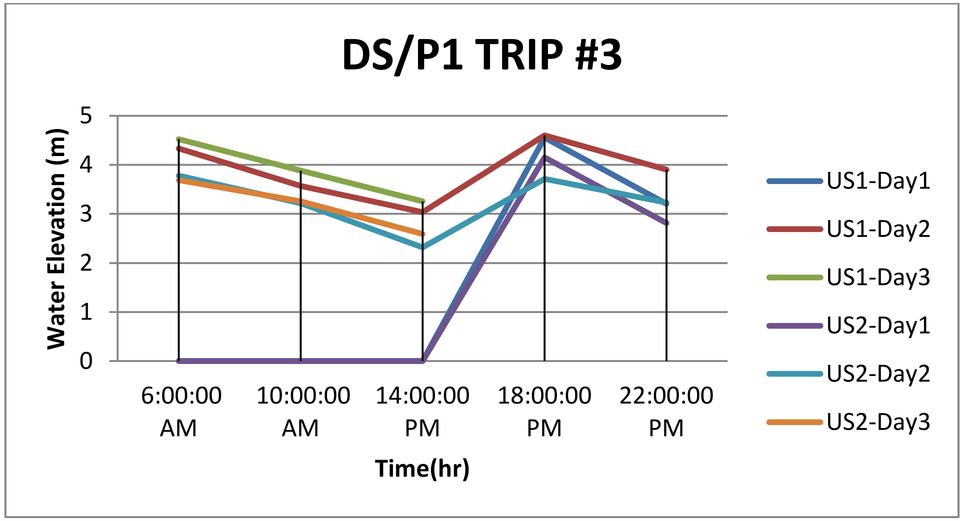

US/P5
Water Elevation (m)
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Max
Min
Mean

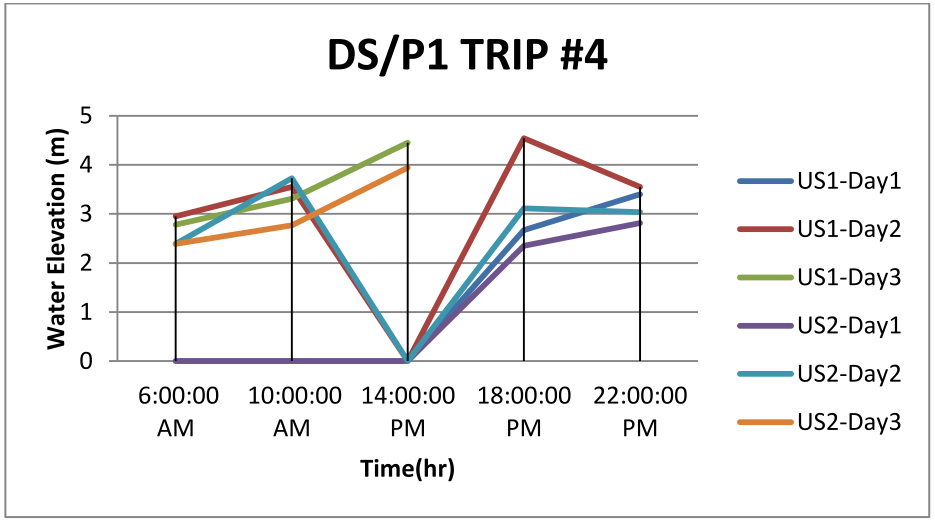

US/P6
Water Elevation (m)
14
12
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Max
Min
Mean

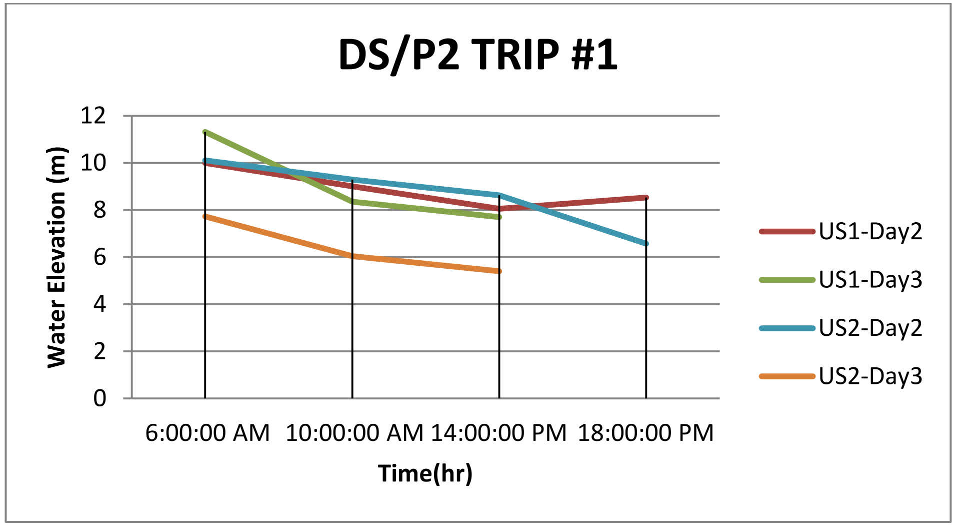
GRAPHS OF WATER ELEVATION VS TIME (DOWNSTREAM)

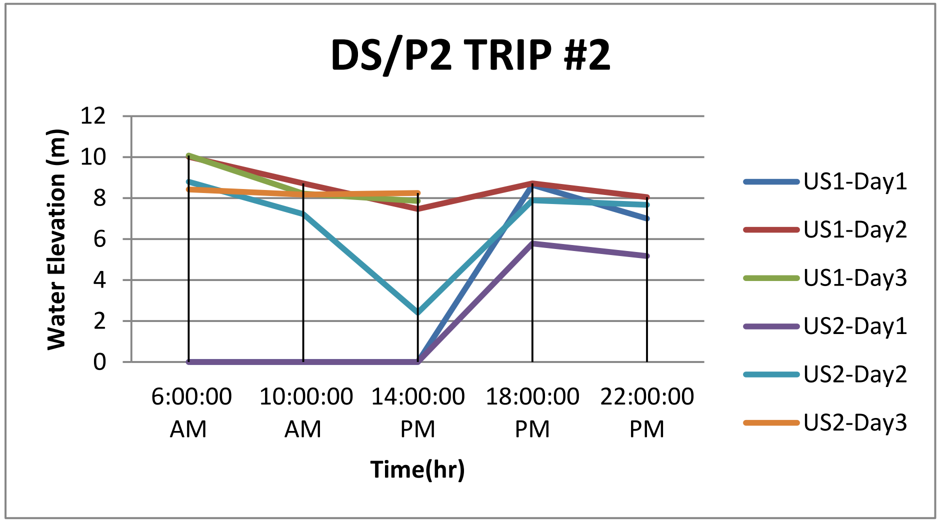









DS/P2 TRIP #1
Water Elevation (m)
12
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
US1-Day2
US1-Day3
US2-Day2
US2-Day3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Water Elevation (m)
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8
6
4
2
0
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10:00:00 AM
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Time(hr)
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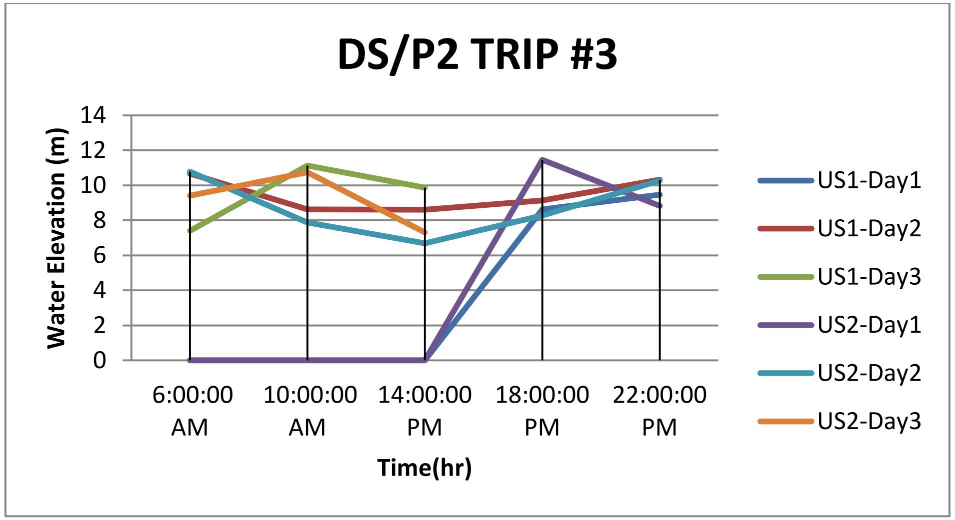
US2-Day2
US2-Day3


DS/P2 TRIP #3
Water Elevation (m)
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12
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
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Time(hr)
US1-Day1
US1-Day2
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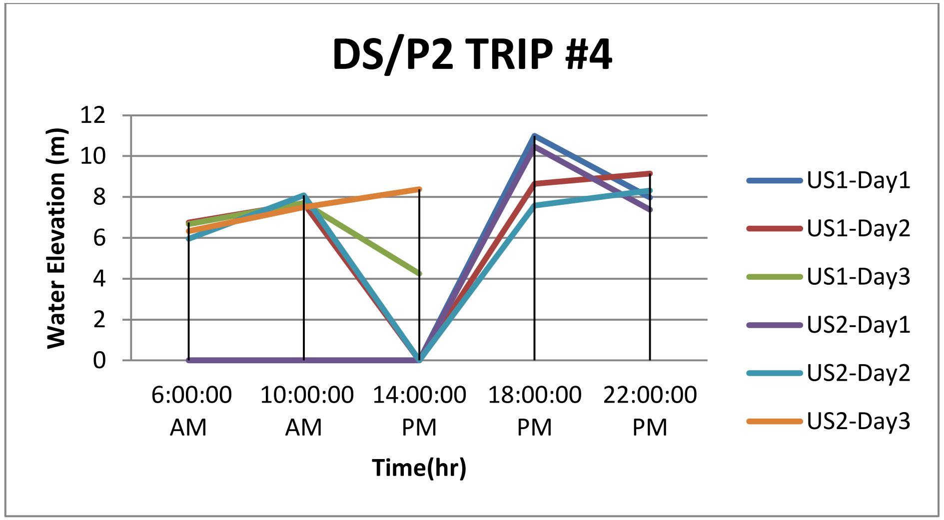
US2-Day2
US2-Day3


DS/P2 TRIP #4
Water Elevation (m)
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4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
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Time(hr)
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US1-Day2
US1-Day3
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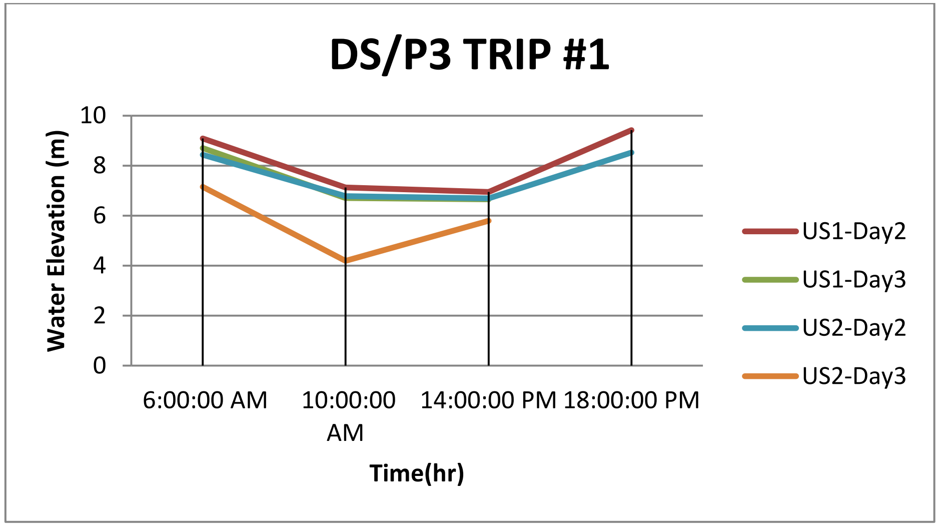
US2-Day2
US2-Day3


DS/P3 TRIP #1
Water Elevation (m)
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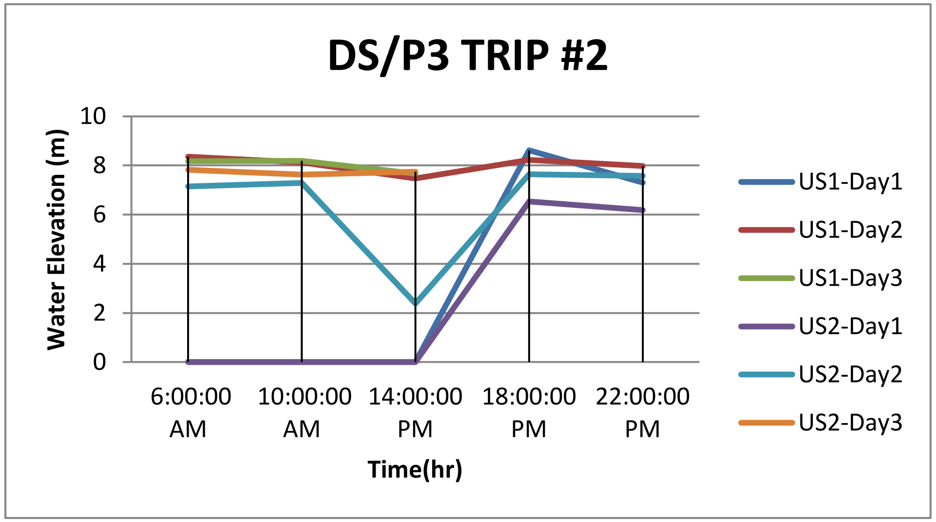
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
US1-Day2
US1-Day3
US2-Day2
US2-Day3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Water Elevation (m)
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4
2
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6:00:00 AM
10:00:00 AM
14:00:00 PM
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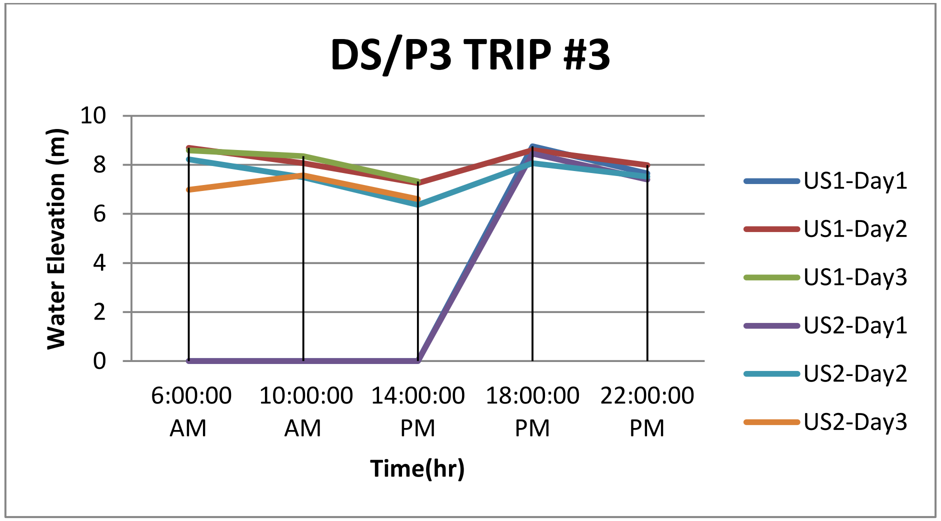
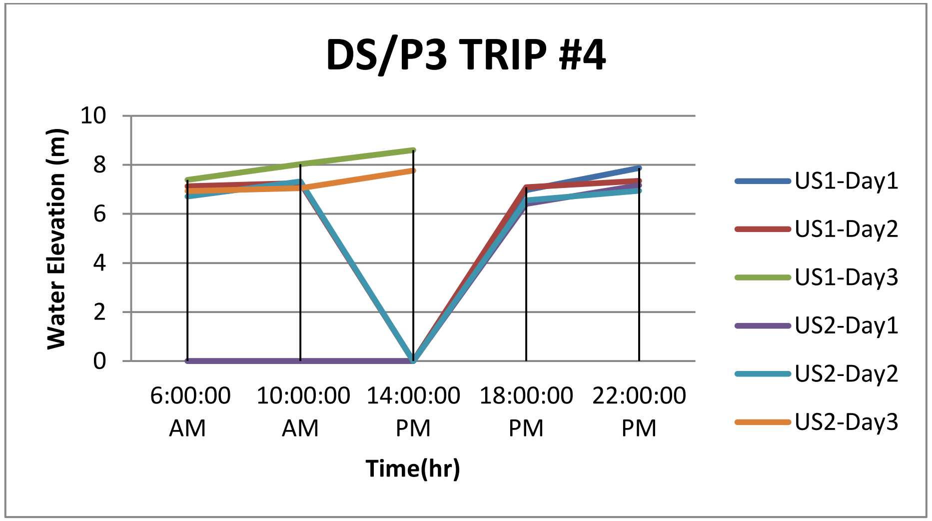
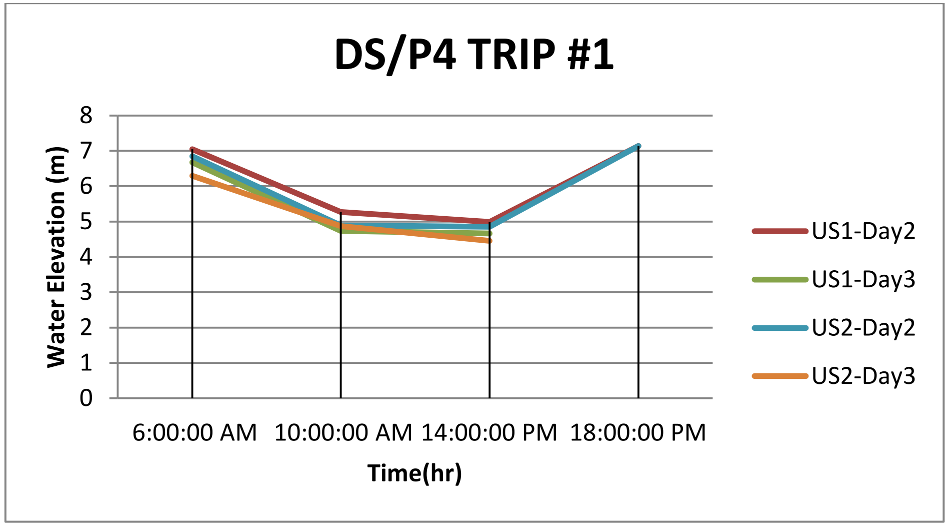
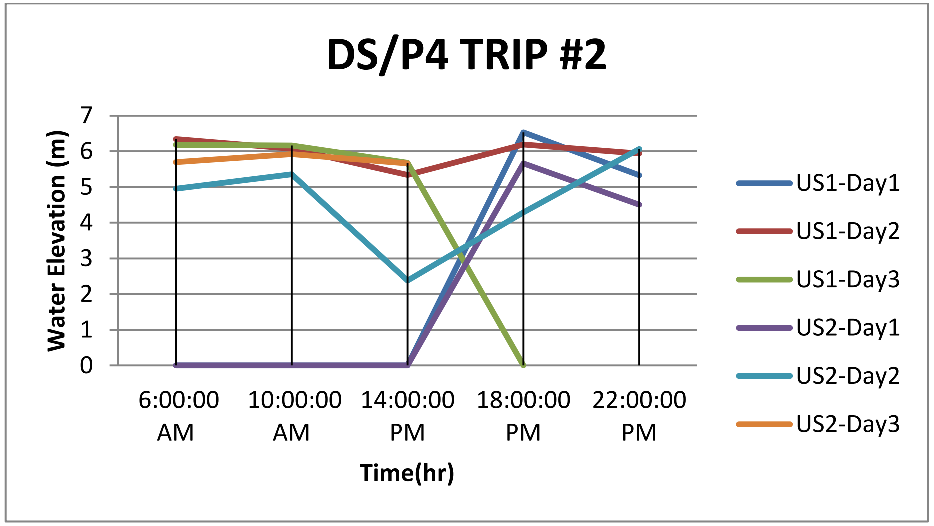
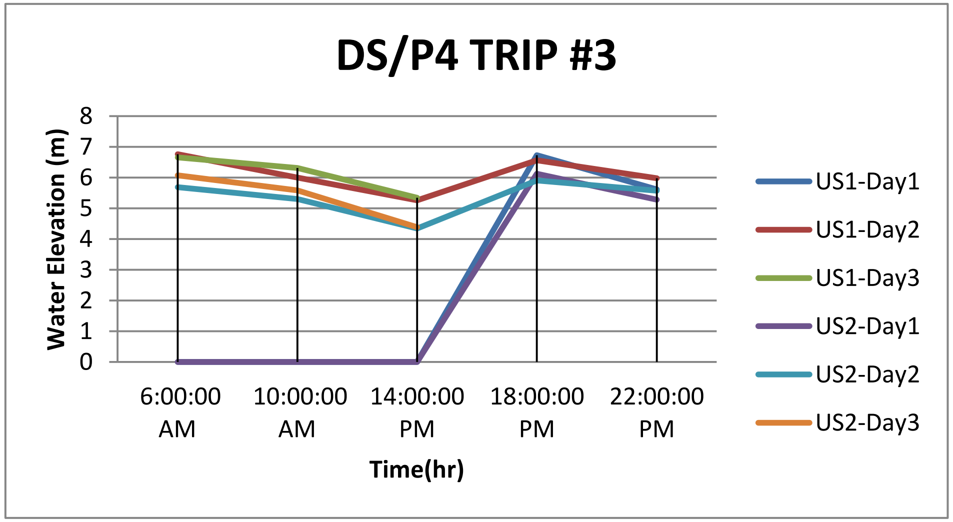
US2-Day2
US2-Day3

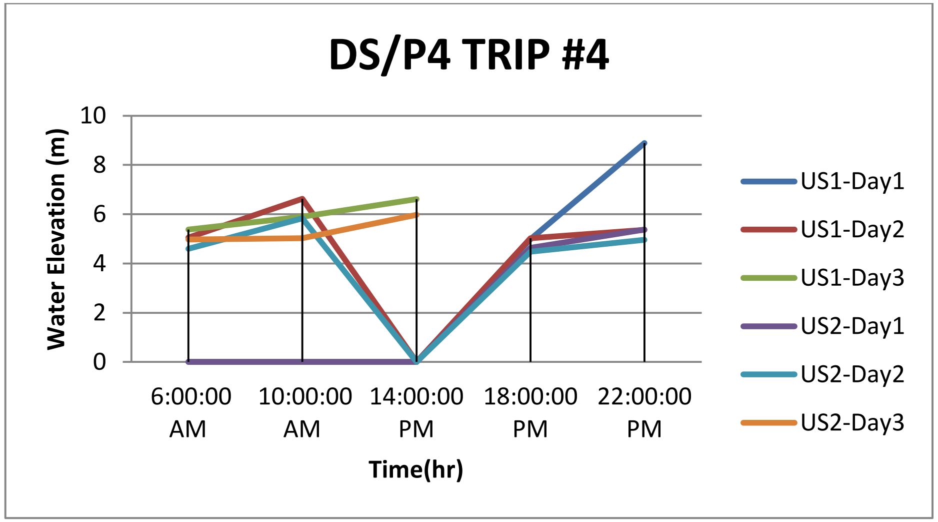

DS/P3 TRIP #3
Water Elevation (m)
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3

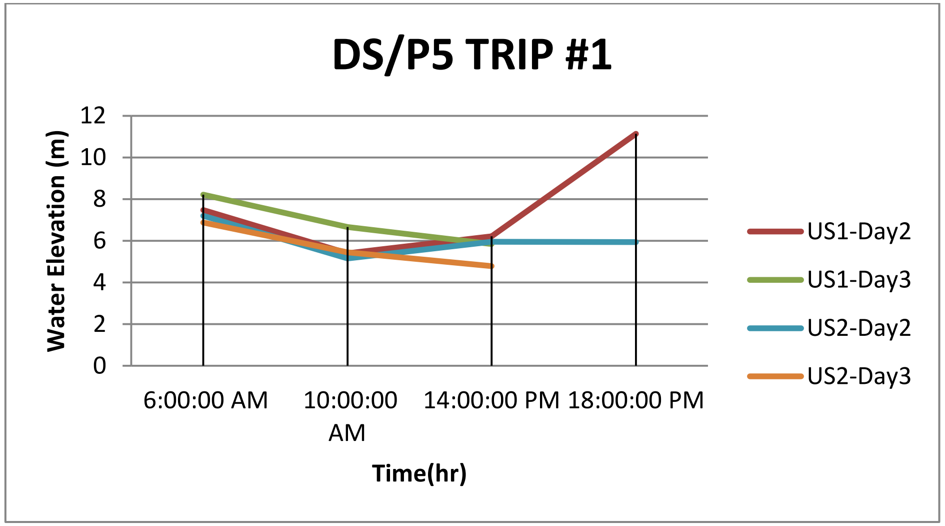

DS/P3 TRIP #4
Water Elevation (m)
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3

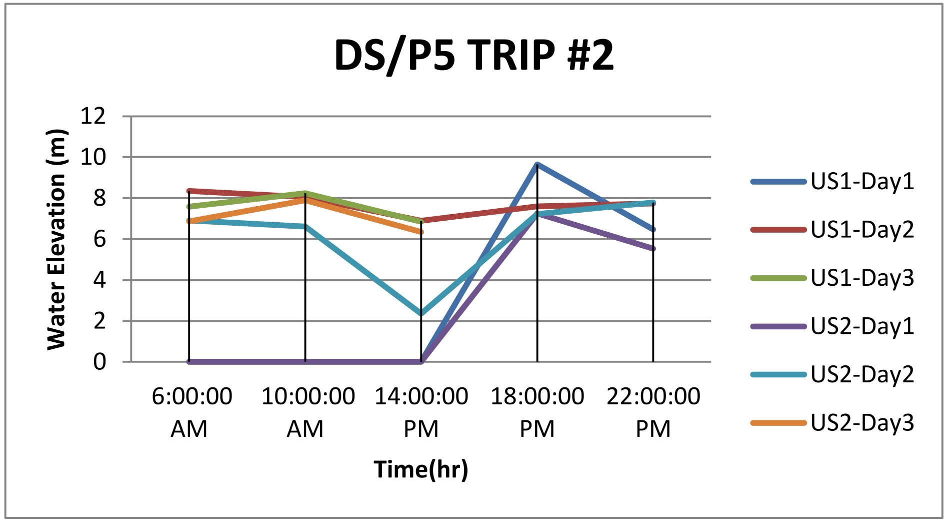

DS/P4 TRIP #1
Water Elevation (m)
8
7
6
5
4
3
2
1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
US1-Day2
US1-Day3
US2-Day2
US2-Day3

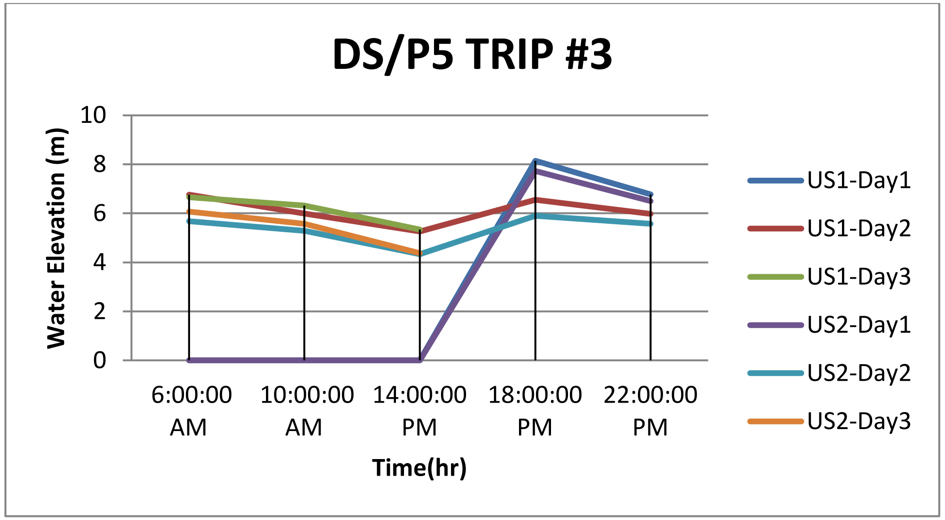

DS/P4 TRIP #2
Water Elevation (m)
7
6
5
4
3
2
1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3

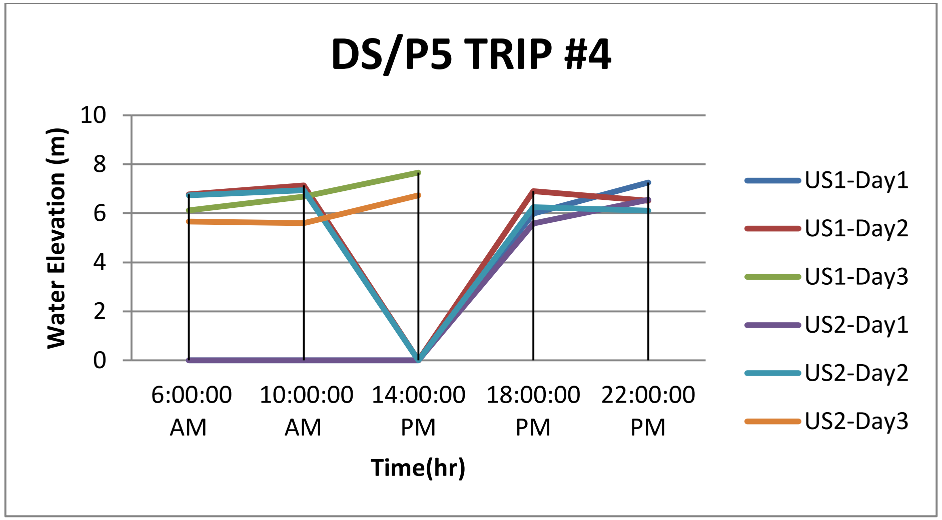

DS/P4 TRIP #3
Water Elevation (m)
8
7
6
5
4
3
2
1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3

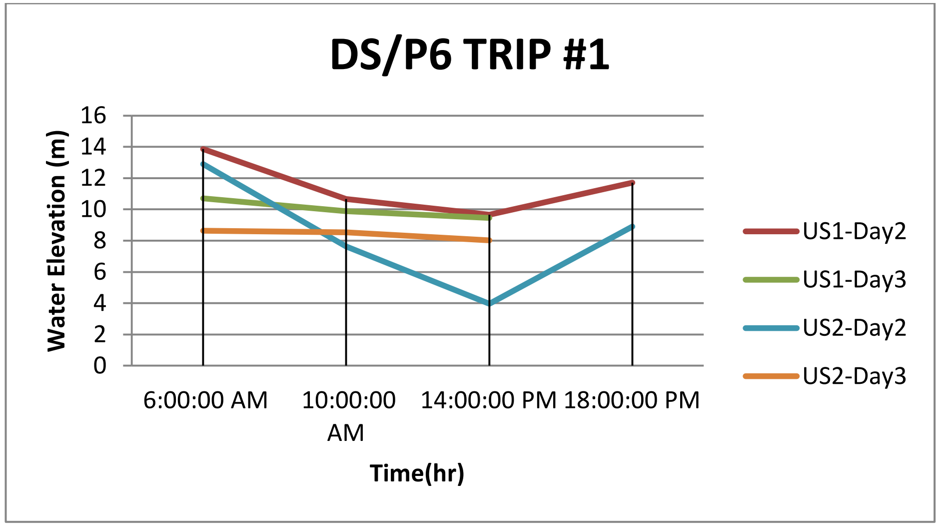

DS/P4 TRIP #4
Water Elevation (m)
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3

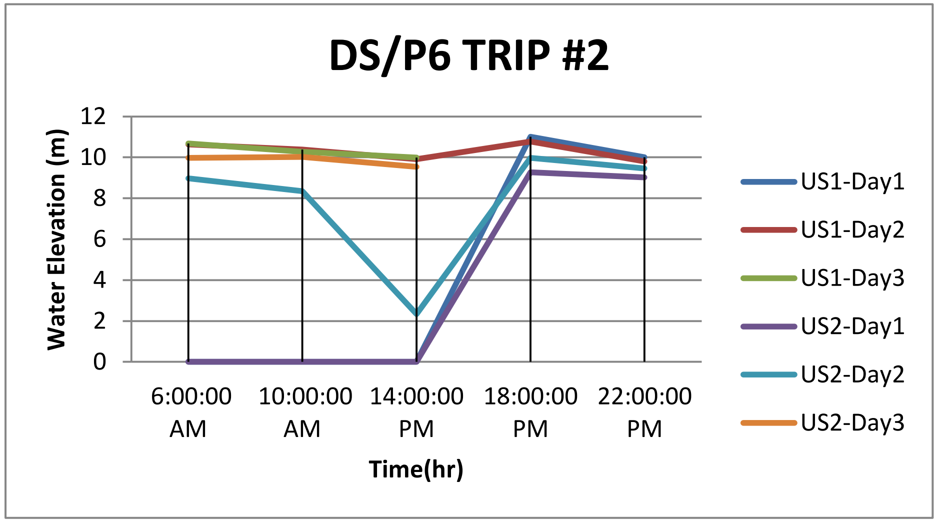

DS/P5 TRIP #1
Water Elevation (m)
12
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
US1-Day2
US1-Day3
US2-Day2
US2-Day3

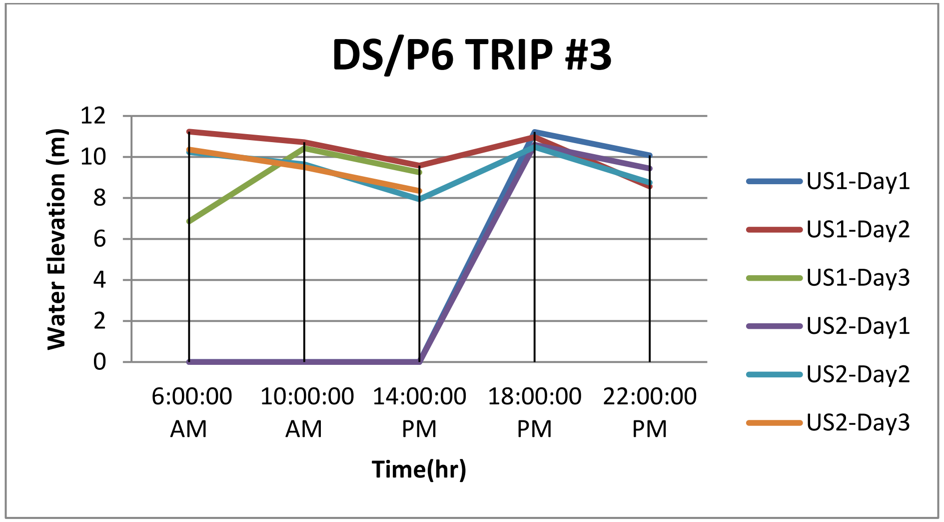

DS/P5 TRIP #2
Water Elevation (m)
12
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3

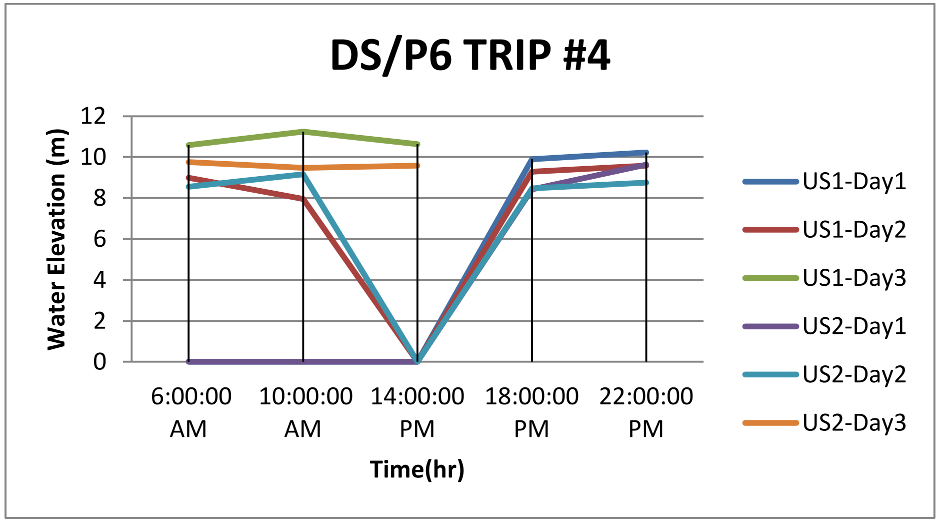

DS/P5 TRIP #3
Water Elevation (m)
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3


DS/P5 TRIP #4
Water Elevation (m)
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3

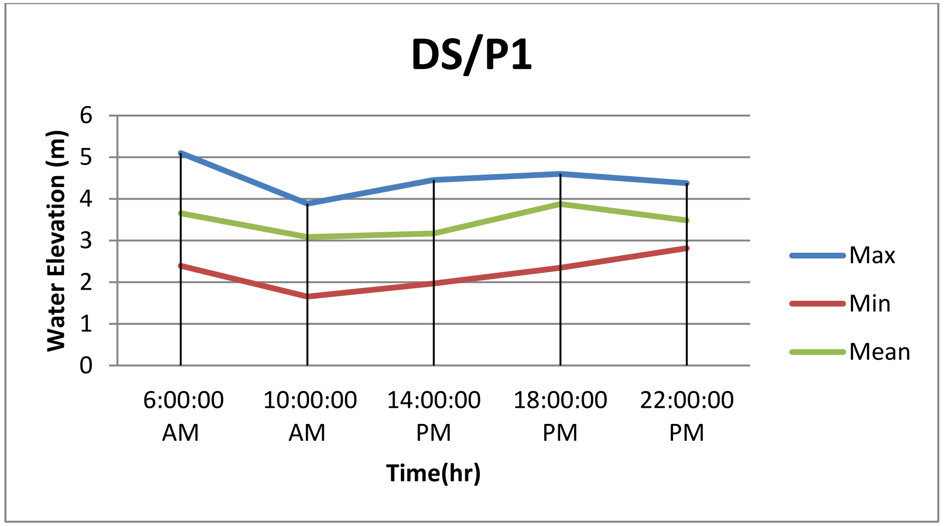

DS/P6 TRIP #1
Water Elevation (m)
16
14
12
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
US1-Day2
US1-Day3
US2-Day2
US2-Day3

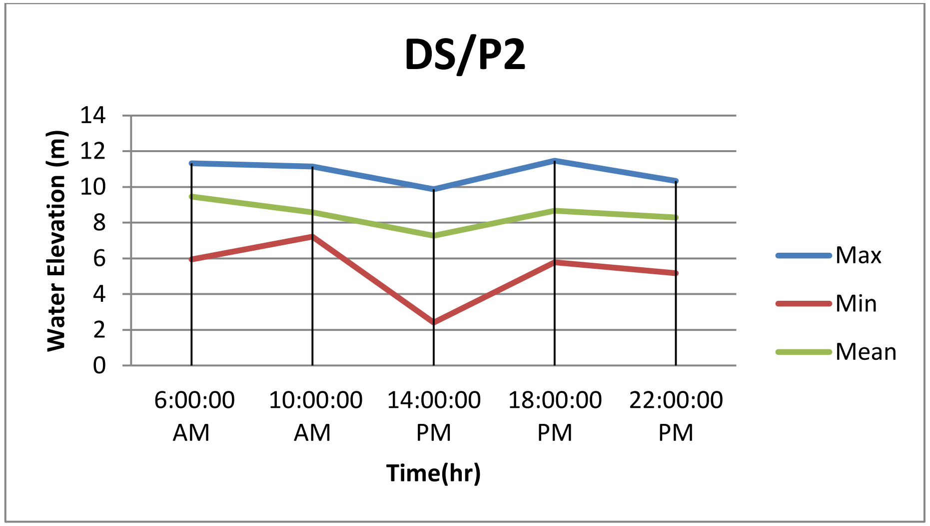

DS/P6 TRIP #2
Water Elevation (m)
12
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3

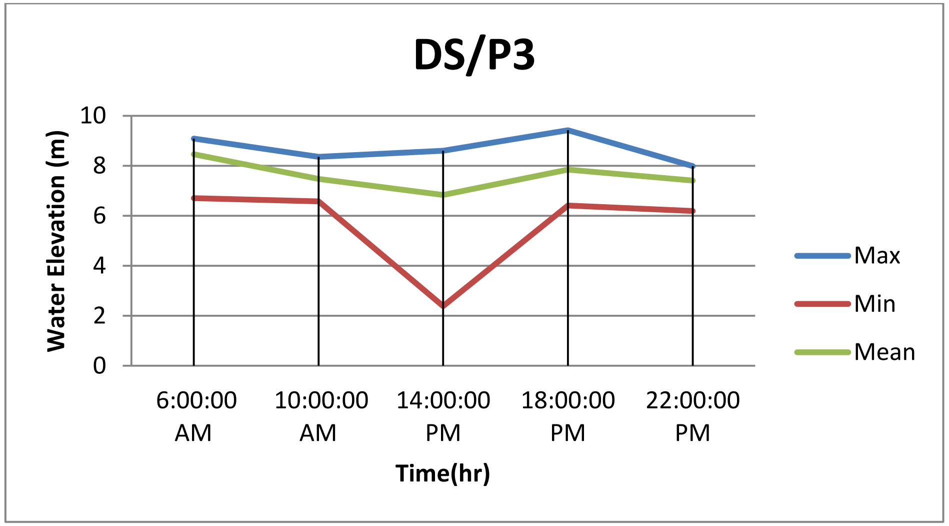

DS/P6 TRIP #3
Water Elevation (m)
12
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3

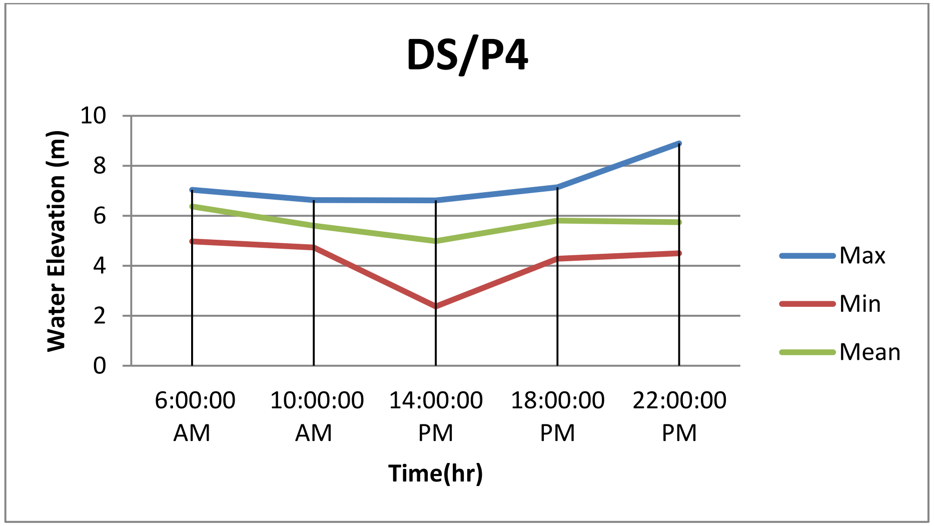

DS/P6 TRIP #4
Water Elevation (m)
12
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
US1-Day1
US1-Day2
US1-Day3
US2-Day1
US2-Day2
US2-Day3

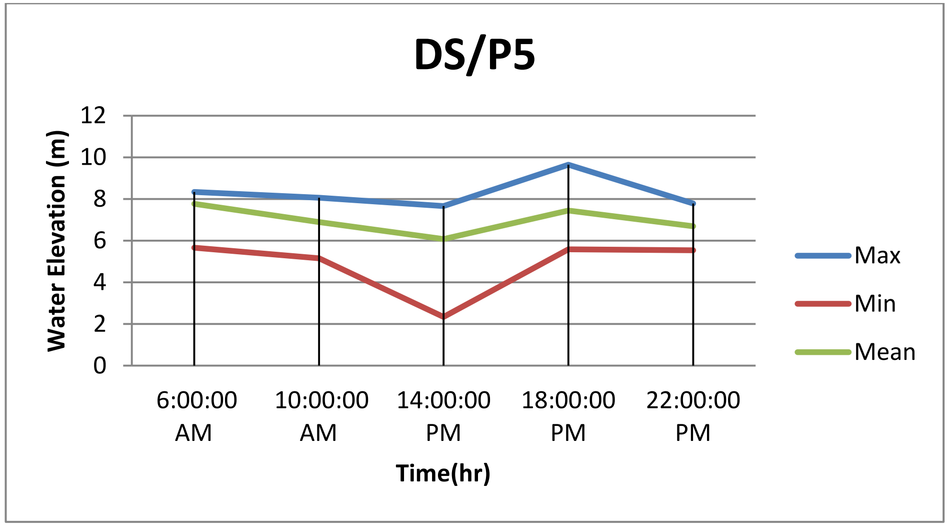
GRAPHS OF MAXIMUM, MINIMUM AND AVERAGE WATER ELEVATION VS TIME (DOWNSTREAM)

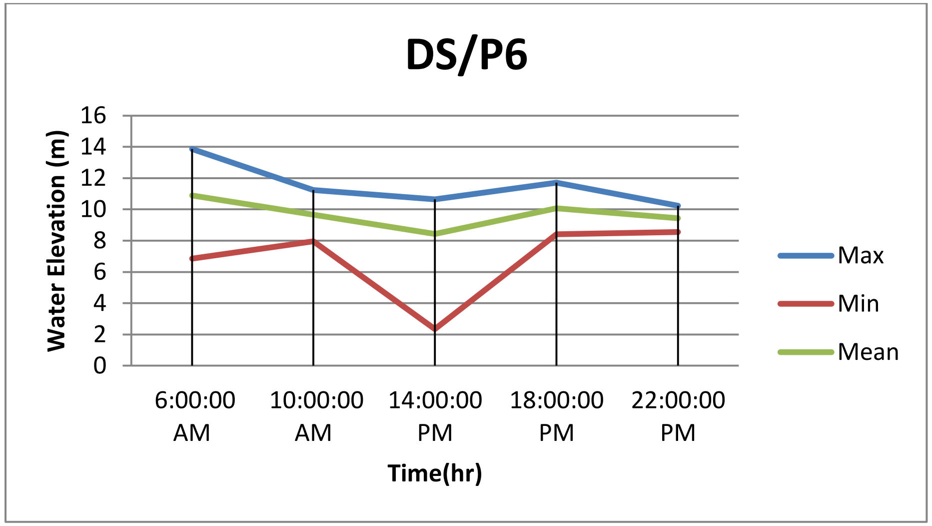









DS/P5
Water Elevation (m)
12
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Max
Min
Mean


DS/P6
Water Elevation (m)
16
14
12
10
8
6
4
2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Max
Min
Mean

APPENDIX B

WATER VELOCITY DATA

WATER VELOCITY DATA (UPSTREAM)

PIER #1

	TRIP1			TRIP2			TRIP3			TRIP4					
Date:	9/3/12-11/3/12			27/4/12-19/4/12			26/5/12-28/5/12			29/6/12-1/7/12					
US/P1	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3			
Time													Max	Min	Mean
6:00:00 AM		0.049	0.209		0.193	0.22		0.324	0.324		0.148	0.07	0.324	0.049	0.192125
10:00:00 AM		0.1	0.411		0.174	0.191		0.16	0.194		0.042	0.203	0.411	0.1	0.210714
14:00:00 PM		0.308	0.212		0.217	0.193		0.102	0.141			0.072	0.308	0.072	0.155625
18:00:00 PM		0.386		0.085	0.22		0.01	0.327		0.661	0.21		0.386	0.01	0.271286
22:00:00 PM				0.066	0.211		0.151	0.115		0.038	0.173		0.211	0.038	0.125667

PIER #2

	TRIP1			TRIP2			TRIP3			TRIP4					
Date:	9/3/12-11/3/12			27/4/12-19/4/12			26/5/12-28/5/12			29/6/12-1/7/12					
US/P1	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3			
Time													Max	Min	Mean
6:00:00 AM		0.113	0.322		0.164	0.227		0.044	0.044		0.091	0.066	0.322	0.044	0.133875
10:00:00 AM		0.055	0.265		0.246	0.204		0.373	0.44		0.2	0.435	0.435	0.055	0.316857
14:00:00 PM		0.715	0.812		0.22	0.197		0.333	0.115			0.066	0.812	0.066	0.30725
18:00:00 PM		0.52		0.211	0.223		0.201	0.27		0.169	0.379		0.52	0.201	0.281857
22:00:00 PM				0.271	0.201		0.463	0.35		0.22	0.013		0.463	0.013	0.253

PIER #3

	TRIP1			TRIP2			TRIP3			TRIP4					
Date:	9/3/12-11/3/12			27/4/12-19/4/12			26/5/12-28/5/12			29/6/12-1/7/12					
US/P1	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3			
Time													Max	Min	Mean
6:00:00 AM		0.169	0.233		0.192	0.221		0.199	0.199		0.093	0.022	0.233	0.022	0.166
10:00:00 AM		0.114	0.267		0.227	0.214		0.466	0.361		0.35	0.186	0.466	0.114	0.312143
14:00:00 PM		0.52	0.385		0.232	0.227		0.225	0.131			0.05	0.52	0.05	0.22125
18:00:00 PM		0.372		0.165	0.229		0.025	0.42		0.216	0.133		0.42	0.025	0.222857
22:00:00 PM				0.244	0.226		0.411	0.013		0.124	0.275		0.411	0.013	0.2155

PIER #4

	TRIP1			TRIP2			TRIP3			TRIP4					
Date:	9/3/12-11/3/12			27/4/12-19/4/12			26/5/12-28/5/12			29/6/12-1/7/12					
US/P1	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3			
Time													Max	Min	Mean
6:00:00 AM		0.167	0.375		0.189	0.221		0.336	0.336		0.037	0.012	0.375	0.012	0.209125
10:00:00 AM		0.33	0.536		0.229	0.215		0.397	0.362		0.023	0.253	0.536	0.023	0.335
14:00:00 PM		0.801	0.299		0.211	0.22		0.236	0.134			0.106	0.801	0.106	0.250875
18:00:00 PM		0.34		0.222	0.22		0.224	0.466		0.266	0.126		0.466	0.126	0.266286
22:00:00 PM				0.257	0.214		0.319	0.229		0.448	0.299		0.448	0.214	0.294333

PIER #5

	TRIP1			TRIP2			TRIP3			TRIP4					
Date:	9/3/12-11/3/12			27/4/12-19/4/12			26/5/12-28/5/12			29/6/12-1/7/12					
US/P1	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3			
Time													Max	Min	Mean
6:00:00 AM		0.193	0.359		0.198	0.2		0.503	0.503		0.14	0.108	0.503	0.108	0.2755
10:00:00 AM		0.23	0.427		0.229	0.215		0.36	0.207		0.31	0.224	0.427	0.207	0.314571
14:00:00 PM		0.595	0.215		0.248	0.231		0.344	0.303			0.108	0.595	0.108	0.2555
18:00:00 PM		0.28		0.293	0.234		0.52	0.451		0.103	0.295		0.52	0.103	0.310857
22:00:00 PM				0.234	0.201		0.524	0.114		0.229	0.232		0.524	0.114	0.255667

PIER #6

	TRIP1			TRIP2			TRIP3			TRIP4					
Date:	9/3/12-11/3/12			27/4/12-19/4/12			26/5/12-28/5/12			29/6/12-1/7/12					
US/P1	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3			
Time													Max	Min	Mean
6:00:00 AM		0.107	0.141		0.192	0.235		0.326	0.326		0.059	0.103	0.326	0.059	0.186125
10:00:00 AM		0.378	0.132		0.271	0.227		0.1	0.255		0.569	0.315	0.569	0.1	0.321
14:00:00 PM		0.523	0.173		0.216	0.213		0.263	0.217			0.202	0.523	0.173	0.225875
18:00:00 PM		0.359		0.115	0.193		0.27	0.206		0.187	0.218	0.315	0.359	0.115	0.266143
22:00:00 PM				0.191	0.207		0.553	0.2		0.284	0.269	0.202	0.553	0.191	0.317667

WATER VELOCITY DATA (DOWNSTREAM)

PIER #1

	TRIP1			TRIP2			TRIP3			TRIP4					
Date:	9/3/12-11/3/12			27/4/12-19/4/12			26/5/12-28/5/12			29/6/12-1/7/12					
US/P1	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3			
Time													Max	Min	Mean
6:00:00 AM		0.304	0.294		0.195	0.22		0.222	0.222		0.306	0.102	0.306	0.102	0.233125
10:00:00 AM		0.376	0.216		0.202	0.226		0.096	0.299		0.075	0.031	0.376	0.031	0.190125
14:00:00 PM		0.557	0.017		0.231	0.169		0.194	0.302			0.148	0.557	0.017	0.231143
18:00:00 PM		0.359		0.28	0.229		0.016	0.275		0.098	0.034		0.359	0.016	0.184429
22:00:00 PM				0.189	0.226		0.479	0.199		0.13	0.127		0.479	0.127	0.225

PIER #2

	TRIP1			TRIP2			TRIP3			TRIP4					
Date:	9/3/12-11/3/12			27/4/12-19/4/12			26/5/12-28/5/12			29/6/12-1/7/12					
US/P1	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3			
Time													Max	Min	Mean
6:00:00 AM		0.249	0.316		0.193	0.225		0.216	0.216		0.259	0.094	0.316	0.094	0.221
10:00:00 AM		0.535	0.297		0.22	0.236		0.1	0.287		0.084	0.141	0.535	0.084	0.2375
14:00:00 PM		0.459	0.291		0.244	0.219		0.23	0.295			0.046	0.459	0.046	0.254857
18:00:00 PM		0.266		0.169	0.239		0.409	0.43		0.226	0.182		0.43	0.169	0.274429
22:00:00 PM				0.242	0.214		0.445	0.098		0.283	0.159		0.445	0.098	0.240167

PIER #3

	TRIP1			TRIP2			TRIP3			TRIP4					
Date:	9/3/12-11/3/12			27/4/12-19/4/12			26/5/12-28/5/12			29/6/12-1/7/12					
US/P1	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3			
Time													Max	Min	Mean
6:00:00 AM		0.148	0.41		0.182	0.216		0.105	0.105		0.063	0.067	0.41	0.063	0.162
10:00:00 AM		0.401	0.272		0.218	0.238		0.131	0.324		0.471	0.054	0.401	0.054	0.263625
14:00:00 PM		0.151	0.303		0.215	0.212		0.042	0.079			0.135	0.303	0.079	0.162429
18:00:00 PM		0.318		0.238	0.234		0.218	0.324		0.13	0.29		0.324	0.13	0.250286
22:00:00 PM				0.25	0.217		0.445	0.409		0.21	0.287		0.445	0.21	0.303

PIER #4

	TRIP1			TRIP2			TRIP3			TRIP4					
Date:	9/3/12-11/3/12			27/4/12-19/4/12			26/5/12-28/5/12			29/6/12-1/7/12					
US/P1	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3			
Time													Max	Min	Mean
6:00:00 AM		0.146	0.4		0.188	0.234		0.397	0.397		0.241	0.101	0.397	0.101	0.263
10:00:00 AM		0.316	0.403		0.216	0.214		0.324	0.1		0.333	0.349	0.403	0.1	0.281875
14:00:00 PM		0.196	0.146		0.243	0.219		0.39	0.291			0.147	0.243	0.146	0.233143
18:00:00 PM		0.187		0.266	0.236		0.18	0.342		0.149	0.316		0.342	0.149	0.239429
22:00:00 PM				0.247	0.243		0.344	0.304		0.356	0.275		0.356	0.243	0.294833

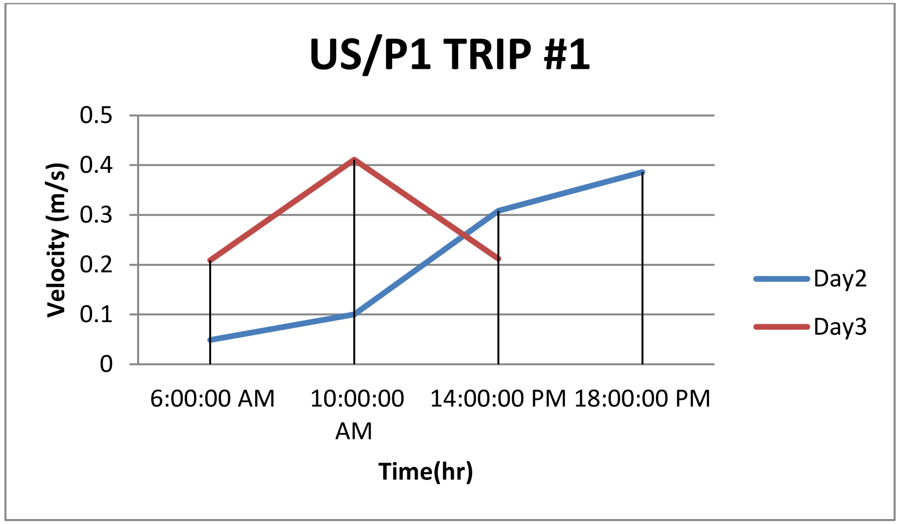
PIER #5

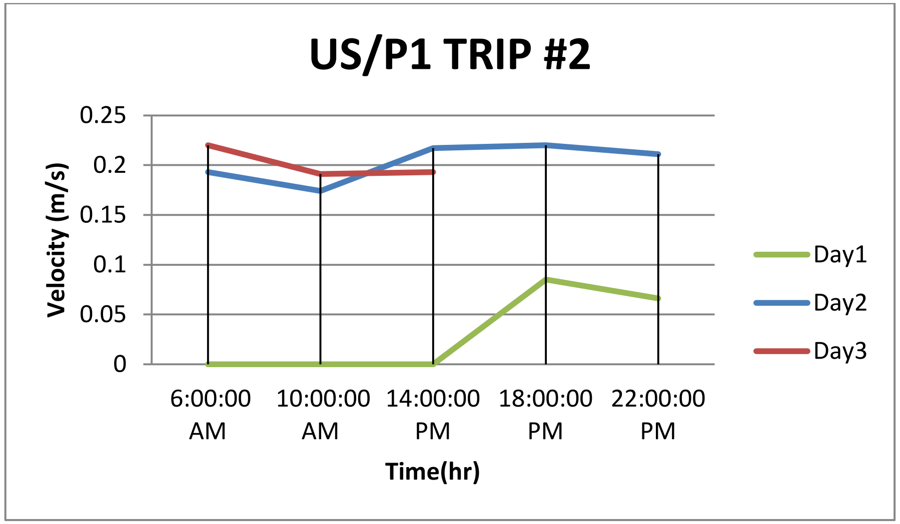
	TRIP1			TRIP2			TRIP3			TRIP4					
Date:	9/3/12-11/3/12			27/4/12-19/4/12			26/5/12-28/5/12			29/6/12-1/7/12					
US/P1	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3			
Time													Max	Min	Mean
6:00:00 AM		0.125	0.4		0.186	0.229		0.365	0.365		0.512	0.128	0.512	0.125	0.28875
10:00:00 AM		0.589	0.439		0.236	0.217		0.104	0.201		0.404	0.159	0.589	0.104	0.293625
14:00:00 PM		0.567	0.354		0.215	0.232		0.359	0.173			0.231	0.567	0.173	0.304429
18:00:00 PM		0.528		0.246	0.247		0.107	0.191		0.196	0.253		0.528	0.107	0.252571
22:00:00 PM				0.257	0.219		0.483	0.29		0.31	0.253		0.483	0.219	0.302

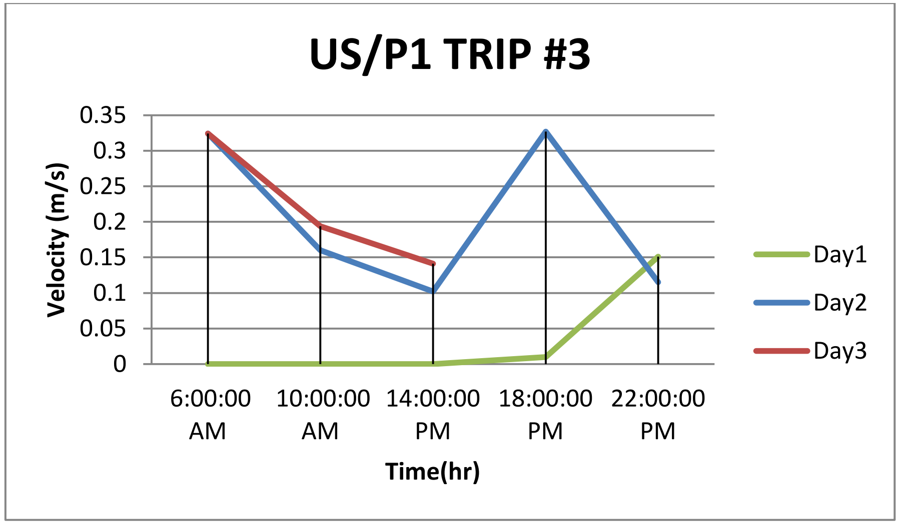
PIER #6

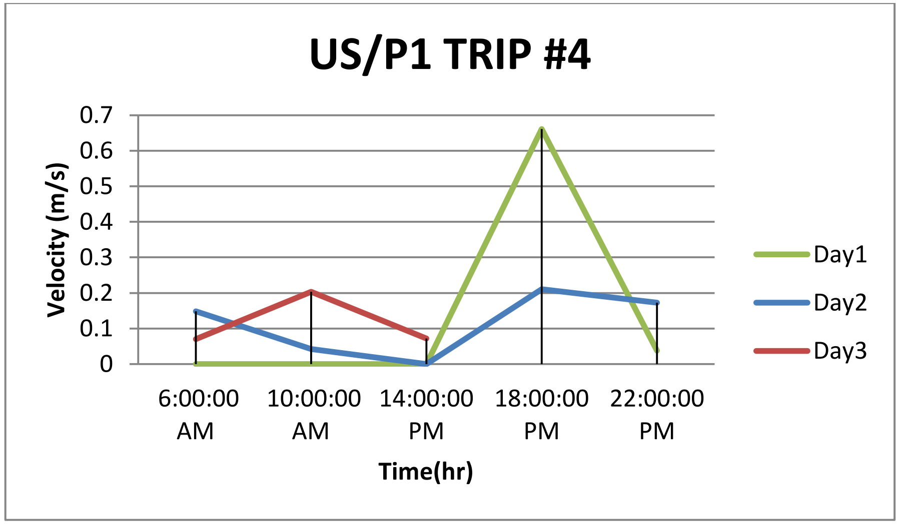
	TRIP1			TRIP2			TRIP3			TRIP4					
Date:	9/3/12-11/3/12			27/4/12-19/4/12			26/5/12-28/5/12			29/6/12-1/7/12					
US/P1	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3	Day1	Day2	Day3			
Time													Max	Min	Mean
6:00:00 AM		0.179	0.401		0.187	0.225		0.263	0.263		0.131	0.072	0.401	0.072	0.215125
10:00:00 AM		0.598	0.294		0.229	0.222		0.302	0.037		0.356	0.08	0.598	0.037	0.26475
14:00:00 PM		0.235	0.334		0.266	0.213		0.307	0.107			0.131	0.334	0.107	0.227571
18:00:00 PM		0.235		0.206	0.234		0.389	0.201		0.031	0.096		0.389	0.031	0.198857
22:00:00 PM				0.213	0.23		0.014	0.218		0.043	0.196		0.213	0.014	0.152333

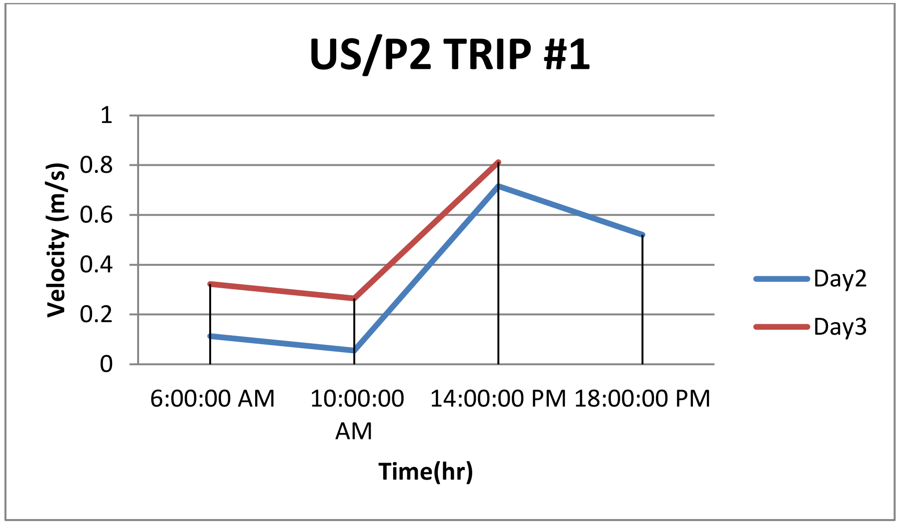
GRAPHS OF WATER VELOCITY VS TIME (UPSTREAM)

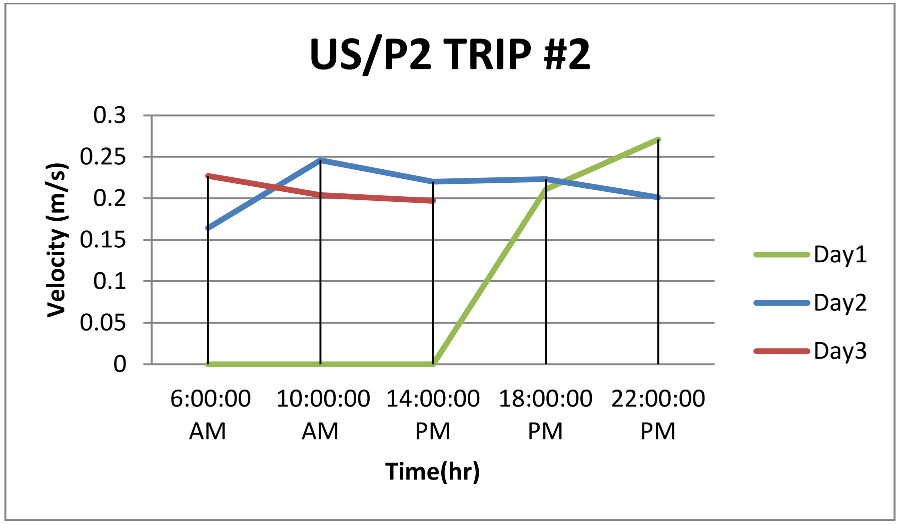


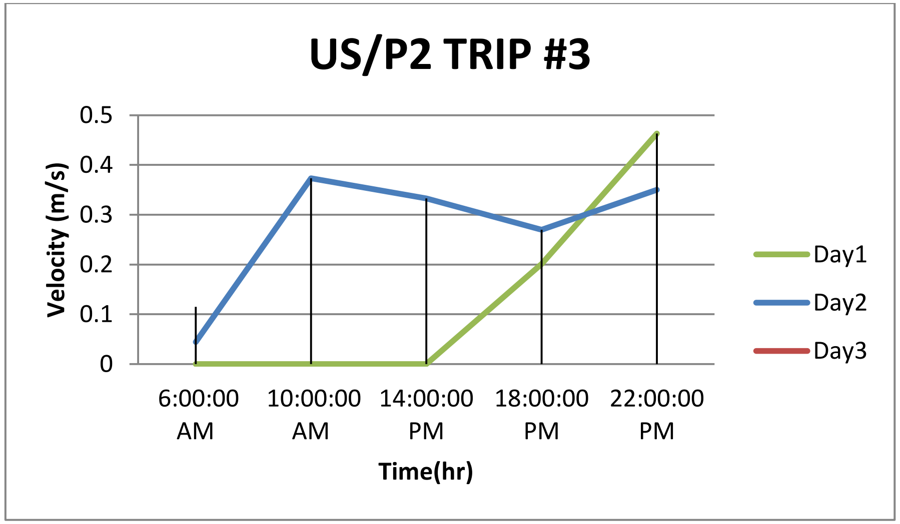


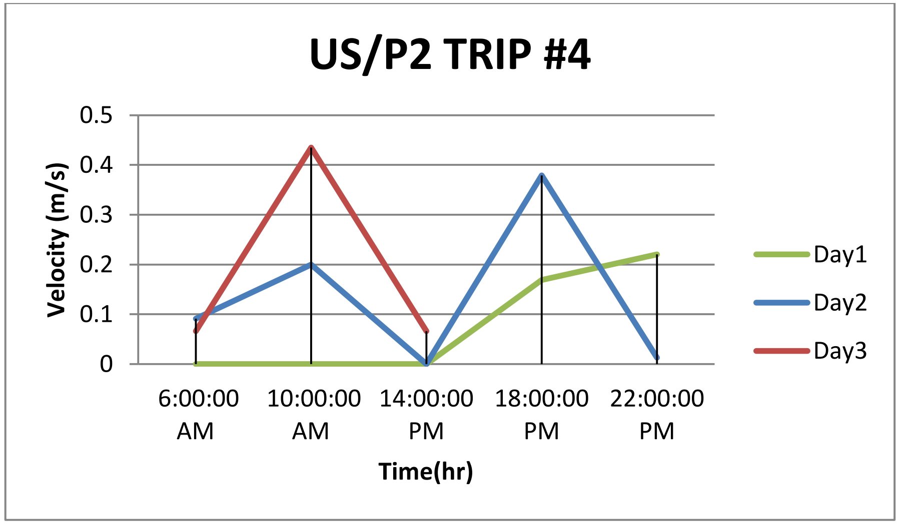





US/P2 TRIP #1
Velocity (m/s)
1
0.8
0.6
0.4
0.2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
Day2
Day3


US/P2 TRIP #2
Velocity (m/s)
0.3
0.25
0.2
0.15
0.1
0.05
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3


US/P2 TRIP #3
Velocity (m/s)
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3


US/P2 TRIP #4
Velocity (m/s)
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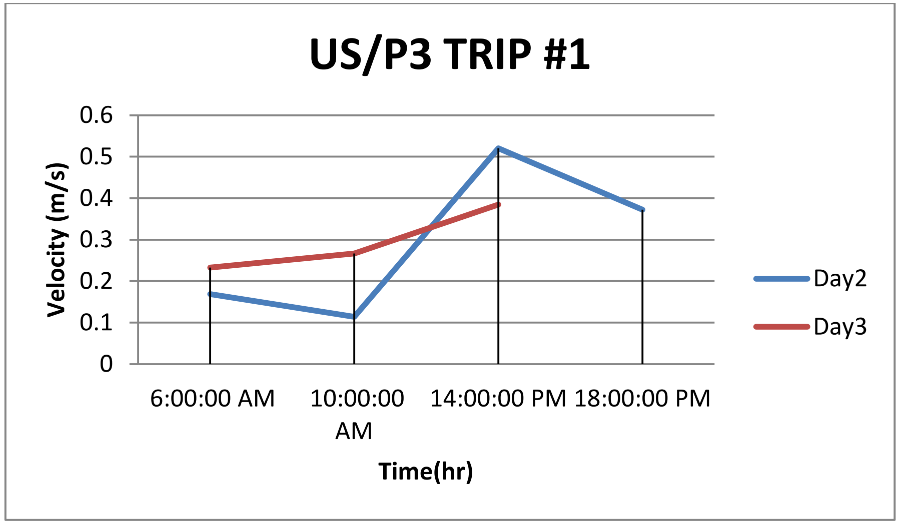
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3


US/P3 TRIP #1
Velocity (m/s)
0.6
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
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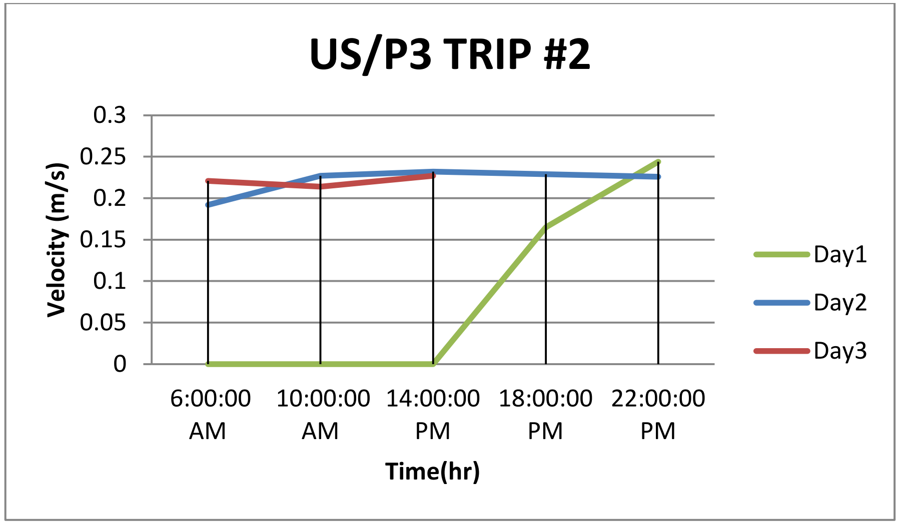
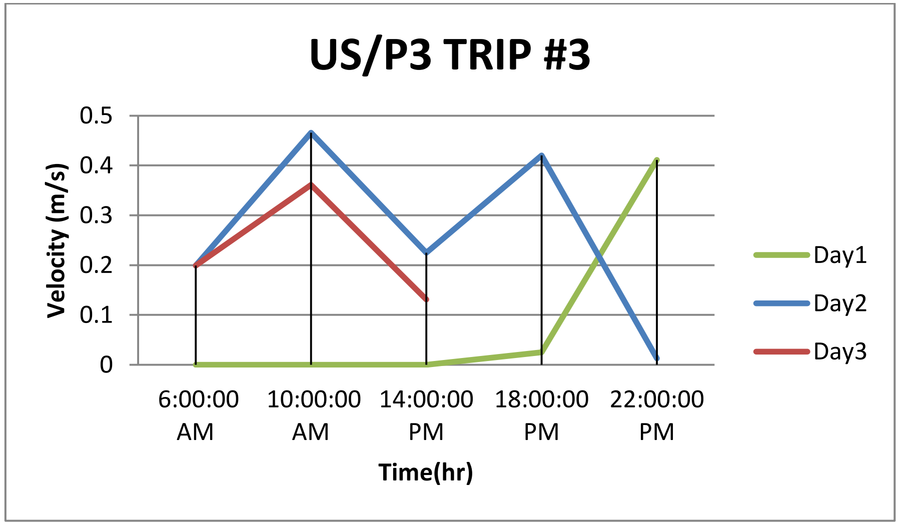
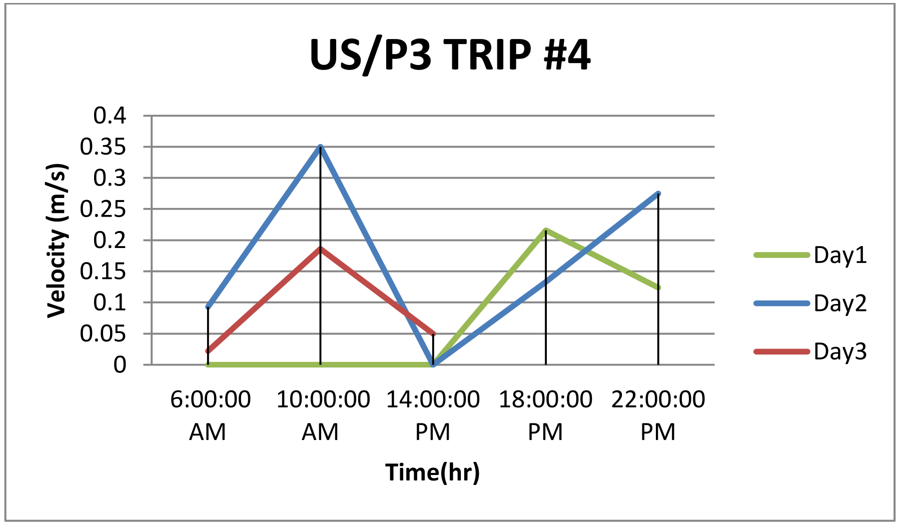
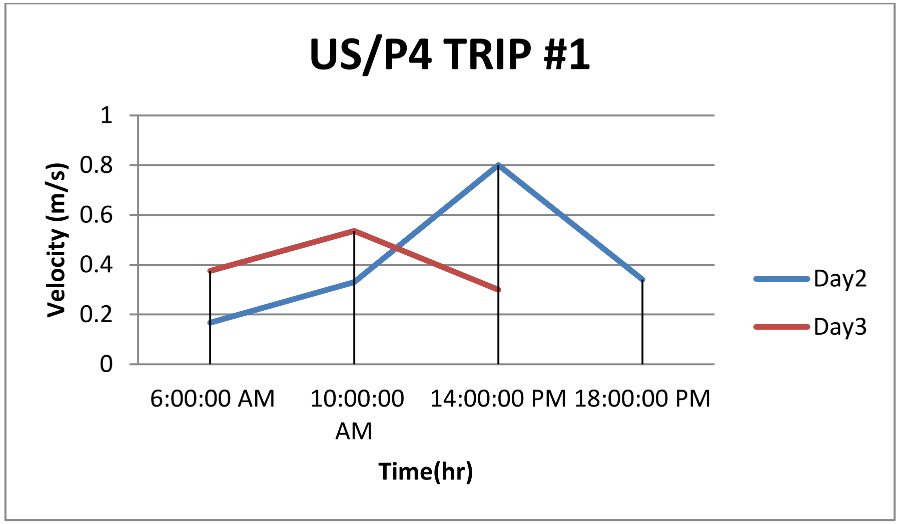
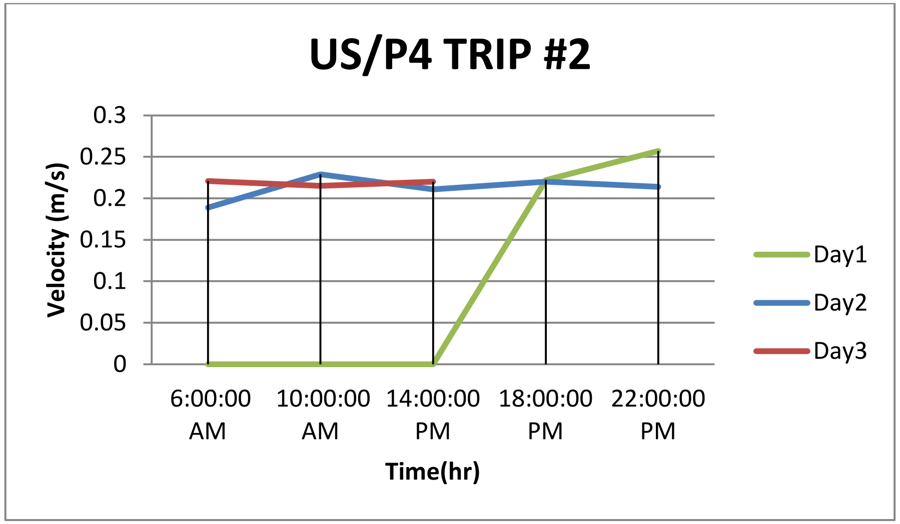
14:00:00 PM
18:00:00 PM
Time(hr)
Day2
Day3

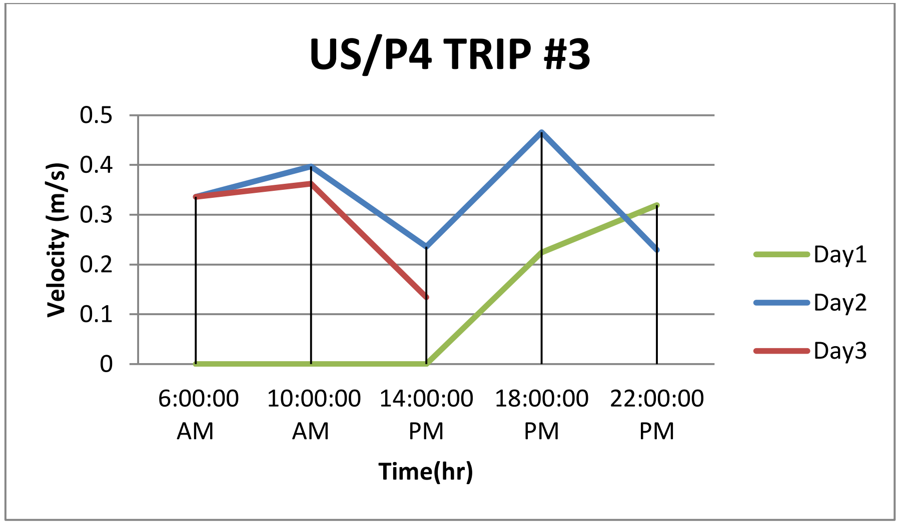

US/P3 TRIP #2
Velocity (m/s)
0.3
0.25
0.2
0.15
0.1
0.05
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3

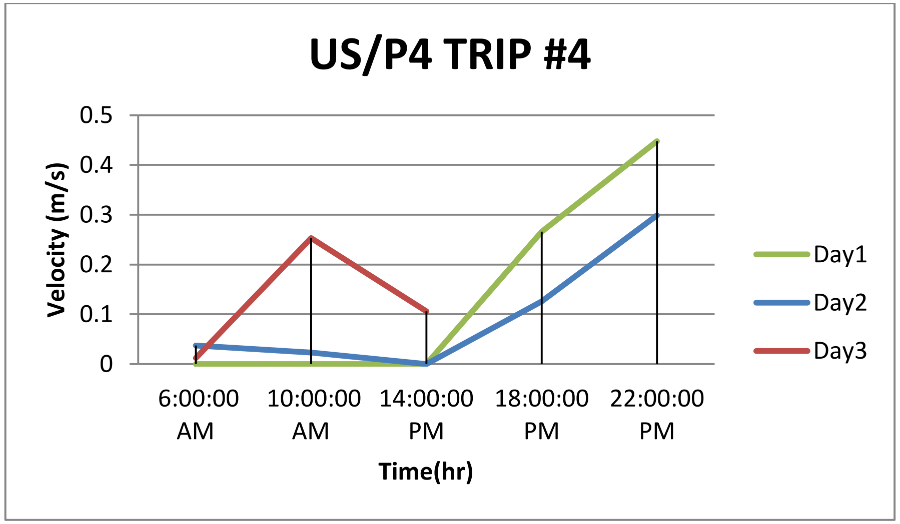

US/P3 TRIP #3
Velocity (m/s)
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3

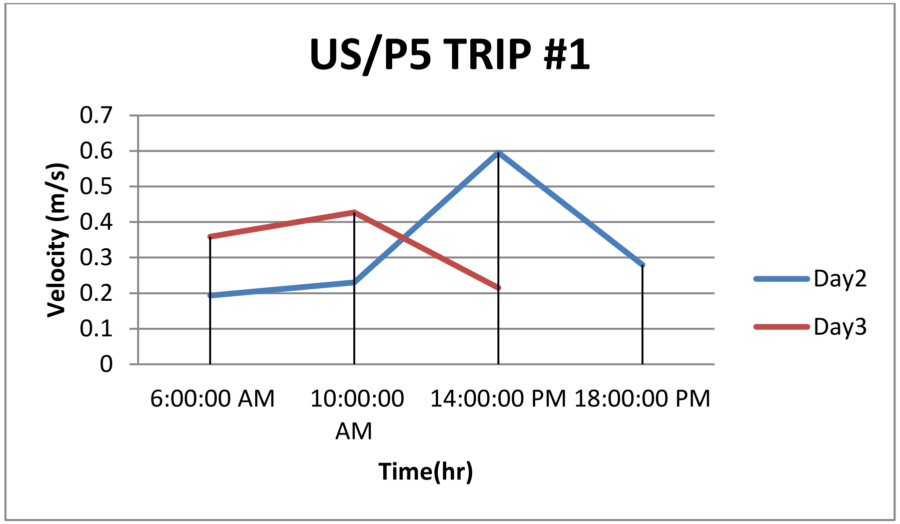

US/P3 TRIP #4
Velocity (m/s)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3

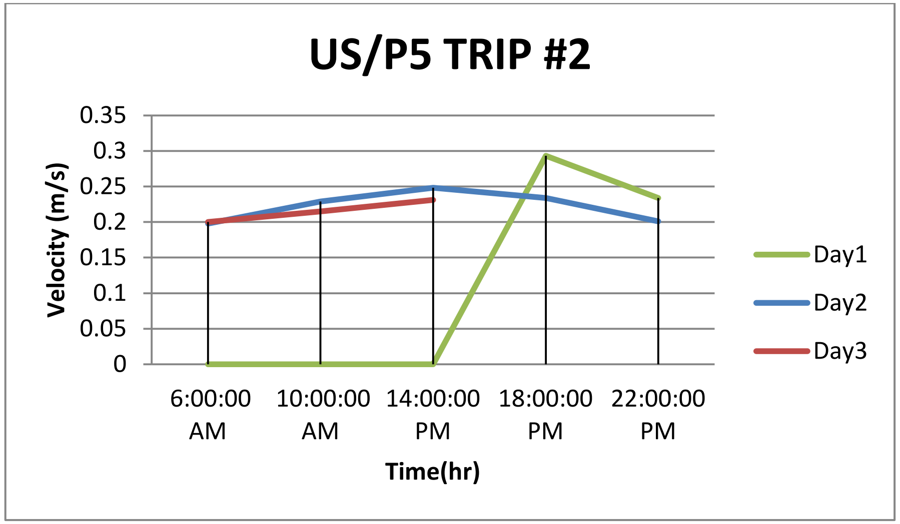

US/P4 TRIP #1
Velocity (m/s)
1
0.8
0.6
0.4
0.2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
Day2
Day3

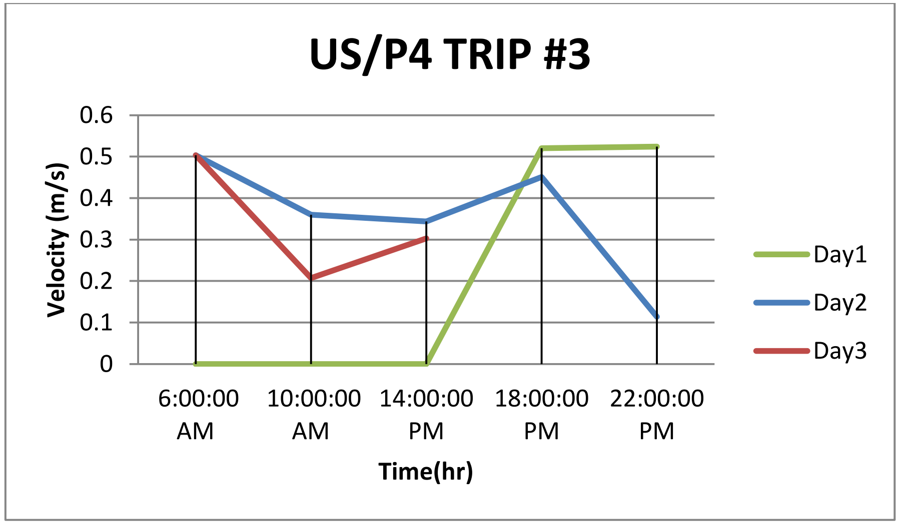

US/P4 TRIP #2
Velocity (m/s)
0.3
0.25
0.2
0.15
0.1
0.05
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3

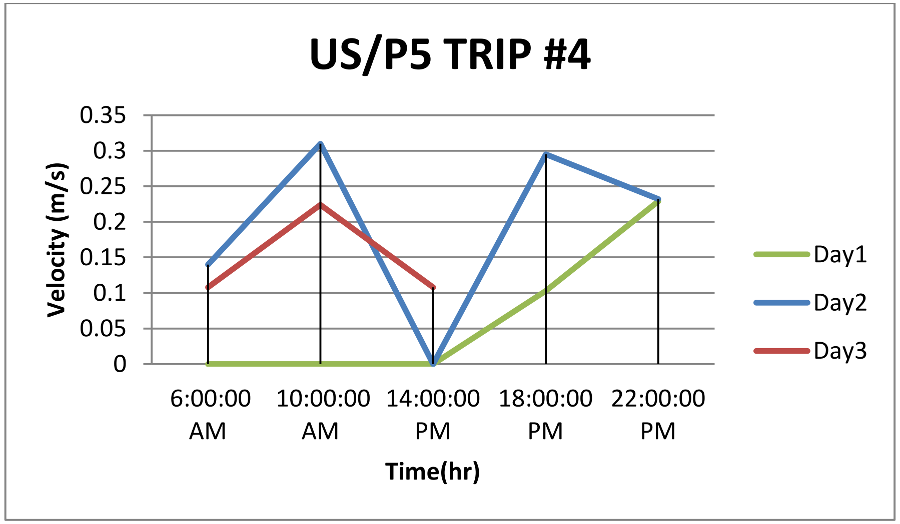

US/P4 TRIP #3
Velocity (m/s)
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3

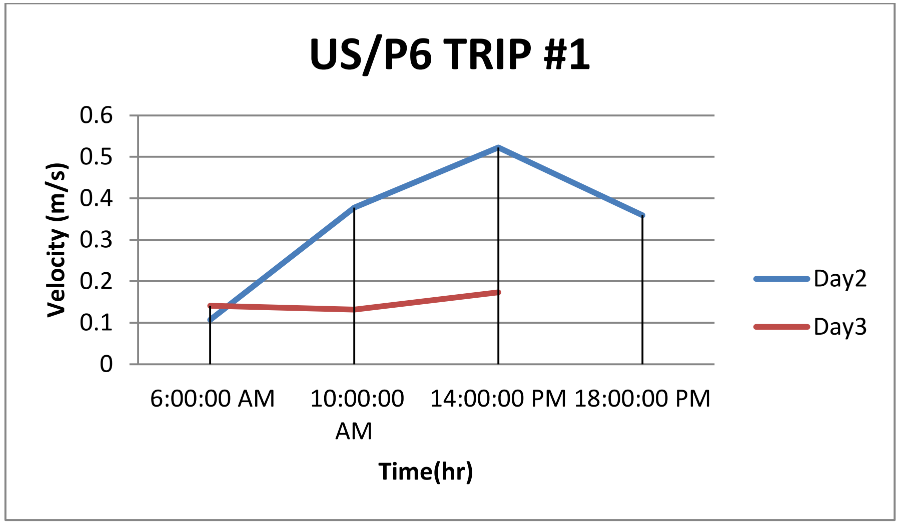

US/P4 TRIP #4
Velocity (m/s)
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3

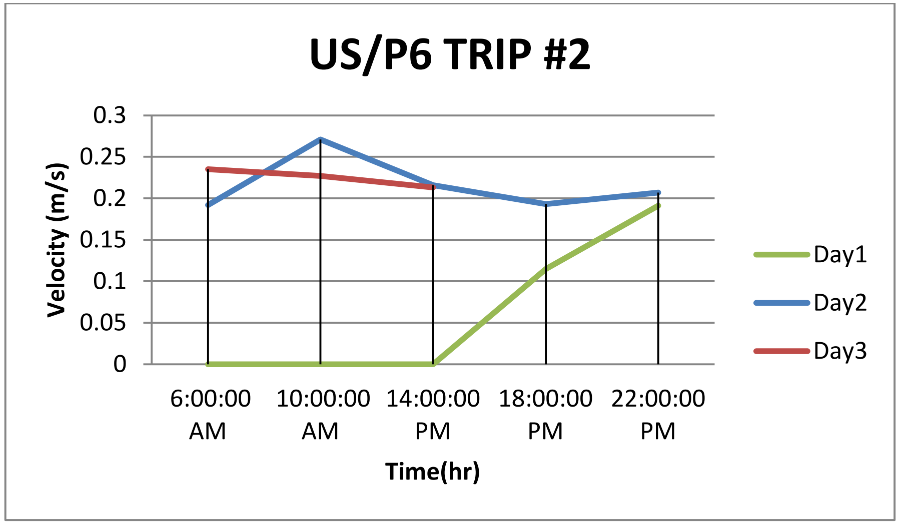

US/P5 TRIP #1
Velocity (m/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
Day2
Day3

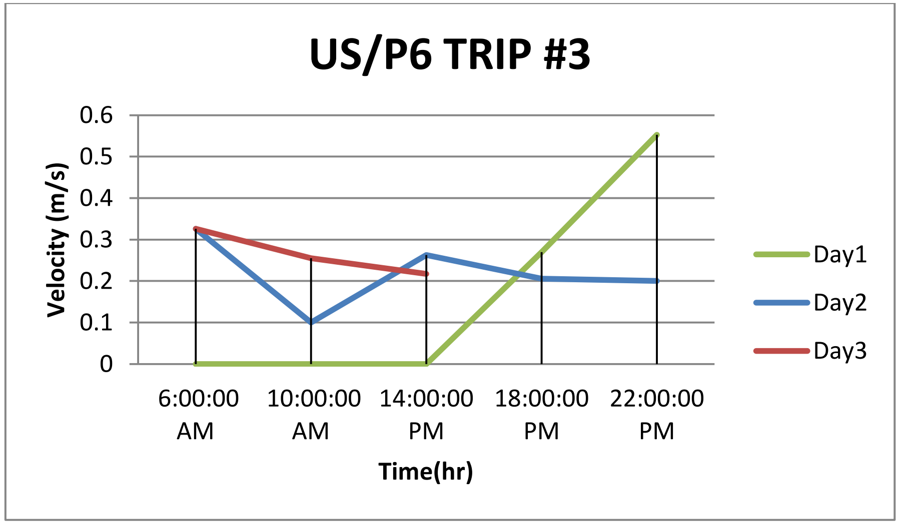

US/P5 TRIP #2
Velocity (m/s)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3

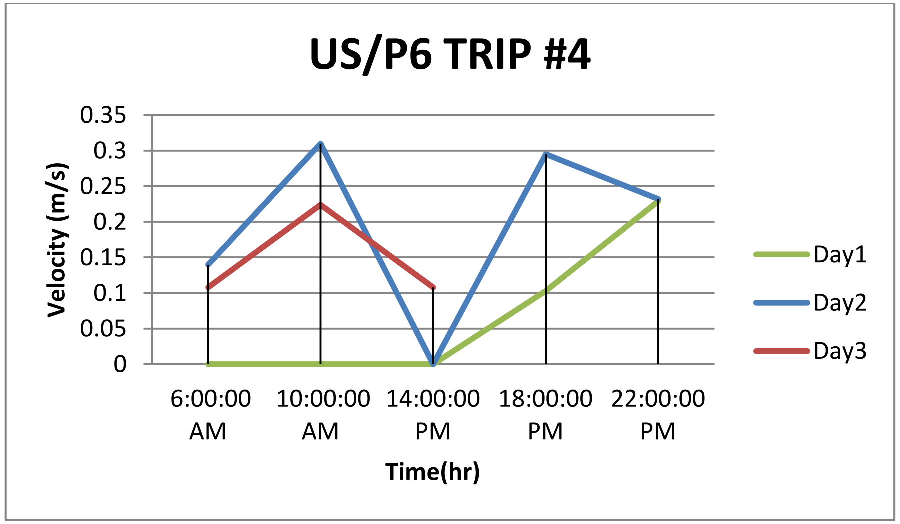

US/P4 TRIP #3
Velocity (m/s)
0.6
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3


US/P5 TRIP #4
Velocity (m/s)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3

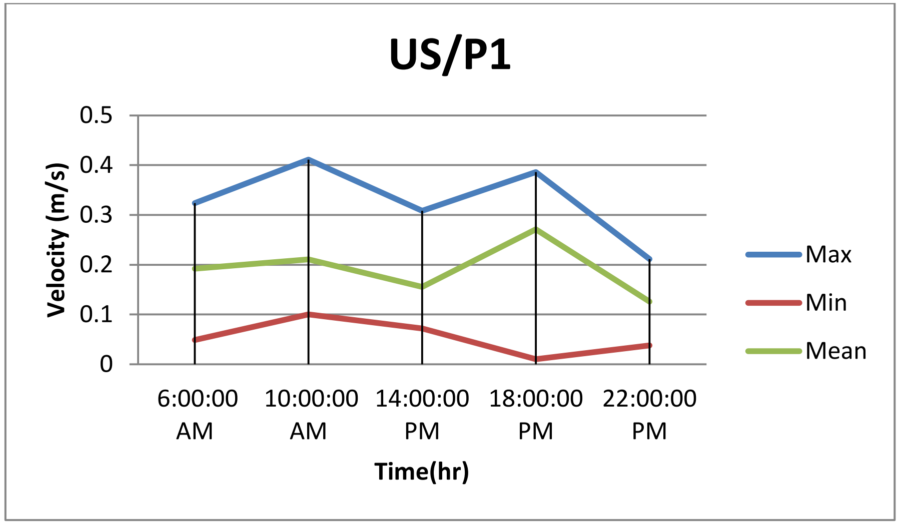

US/P6 TRIP #1
0.6
0.5
0.4
0.3
0.2
0.1
0
Velocity (m/s)
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
Day2
Day3

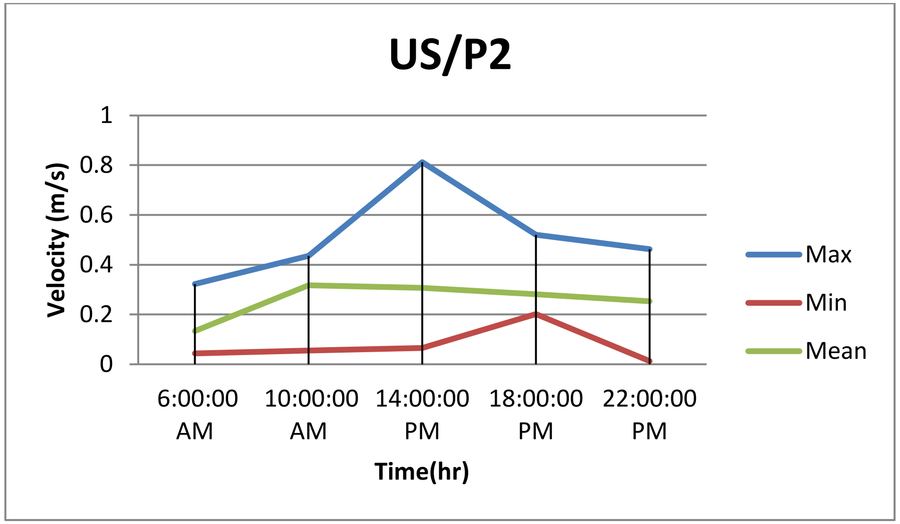

US/P6 TRIP #2
0.3
0.25
0.2
0.15
0.1
0.05
0
Velocity (m/s)
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3

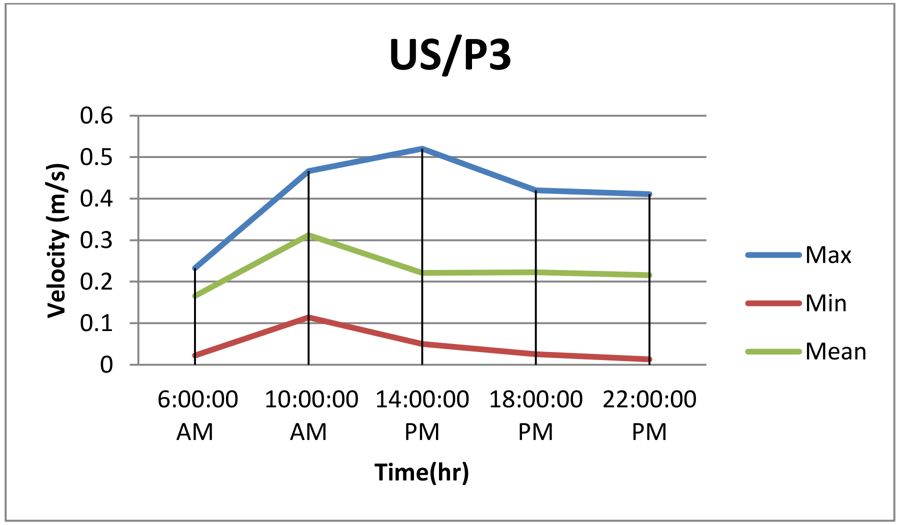

US/P6 TRIP #3
0.6
0.5
0.4
0.3
0.2
0.1
0
Velocity (m/s)
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3

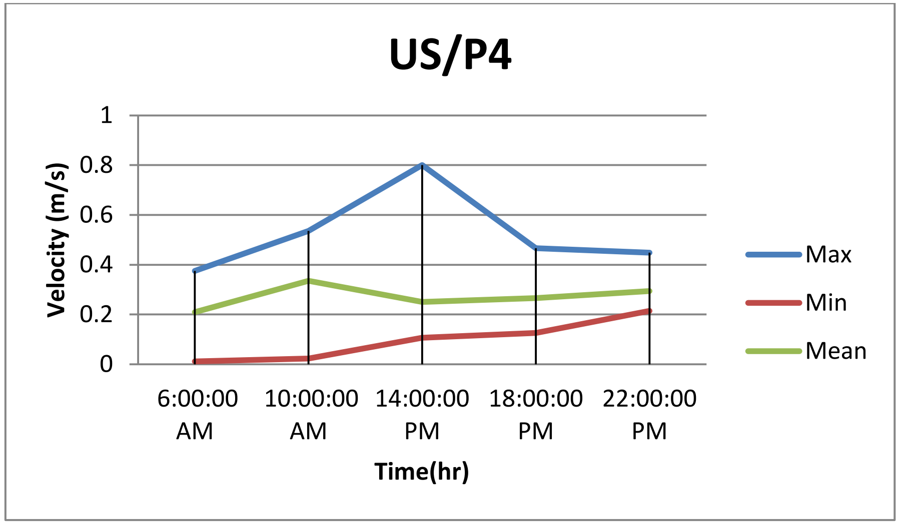

US/P6 TRIP #4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Velocity (m/s)
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3

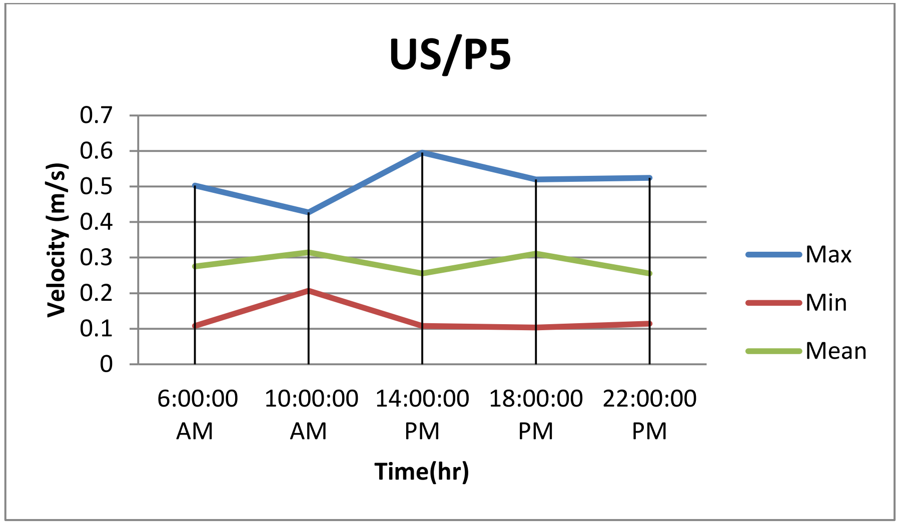
GRAPHS OF MAXIMUM, MINIMUM AND AVERAGE WATER VELOCITY VS TIME (UPSTREAM)

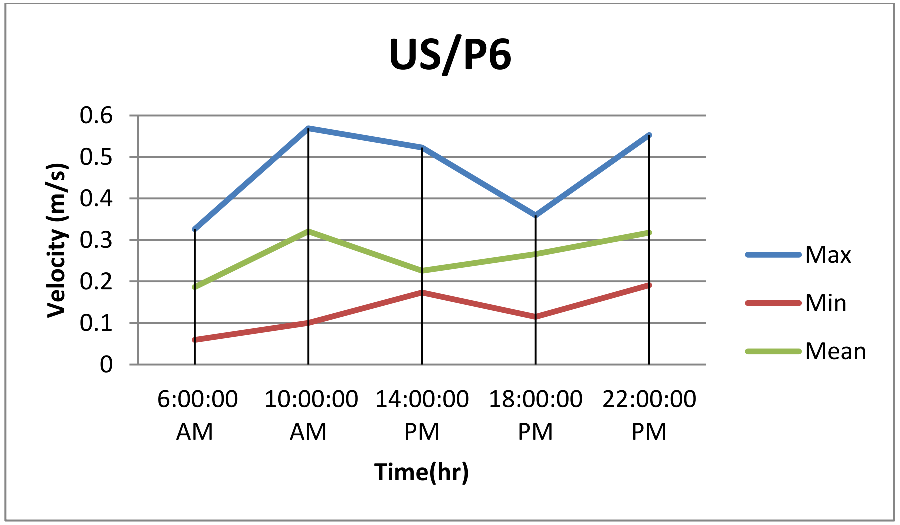




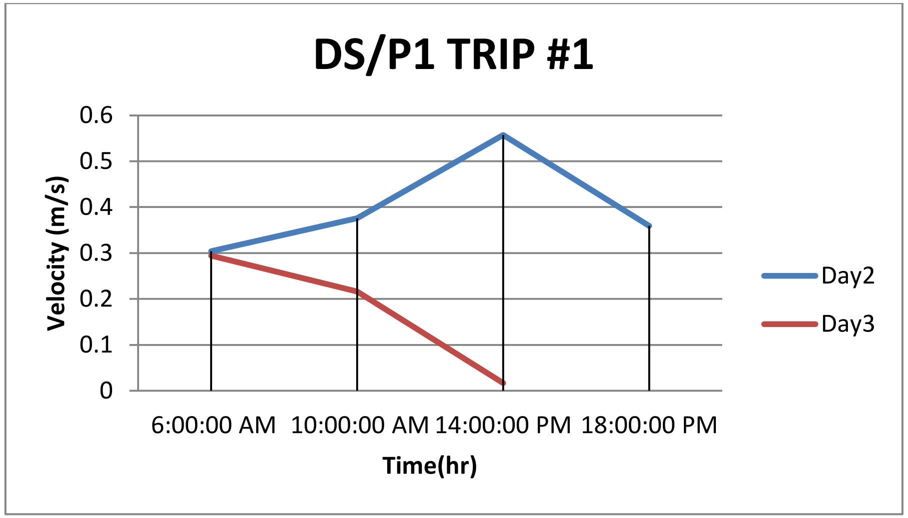


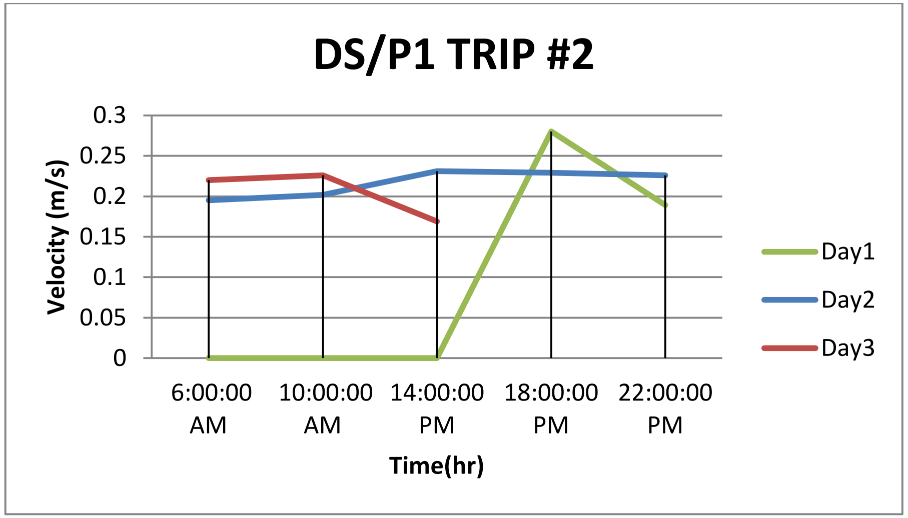

US/P4
Velocity (m/s)
1
0.8
0.6
0.4
0.2
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Max
Min
Mean

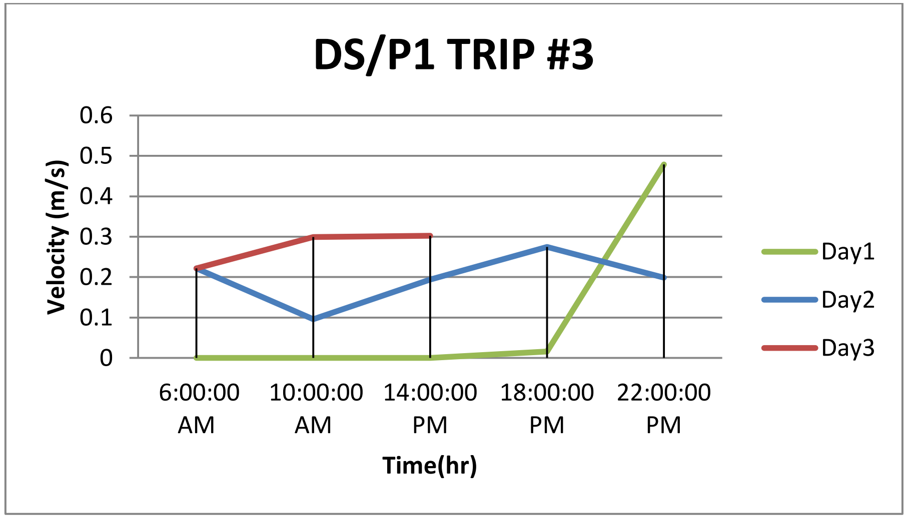

US/P5
Velocity (m/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Max
Min
Mean

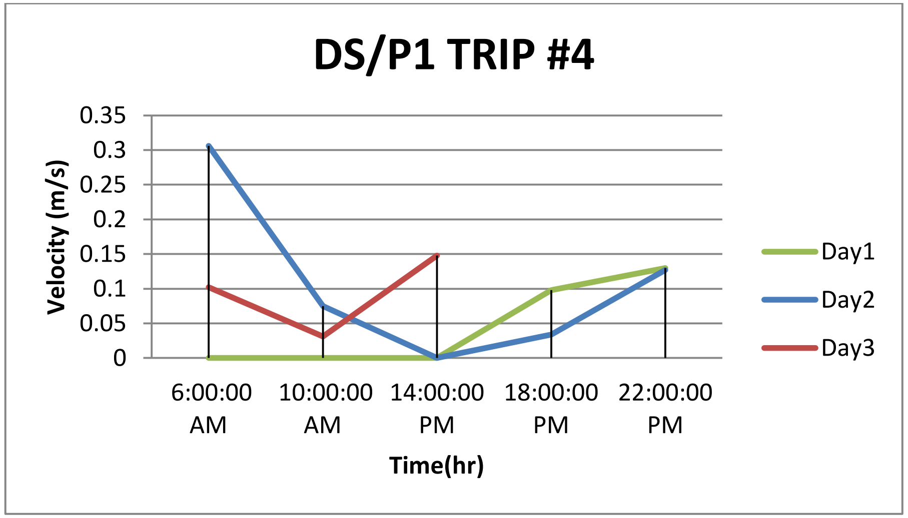

US/P6
Velocity (m/s)
0.6
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Max
Min
Mean

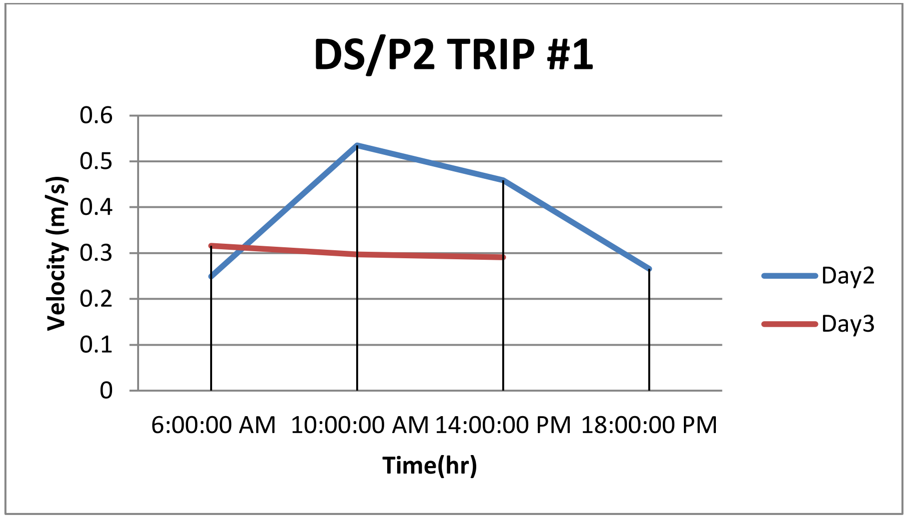
GRAPHS OF WATER VELOCITY VS TIME (DOWNSTREAM)

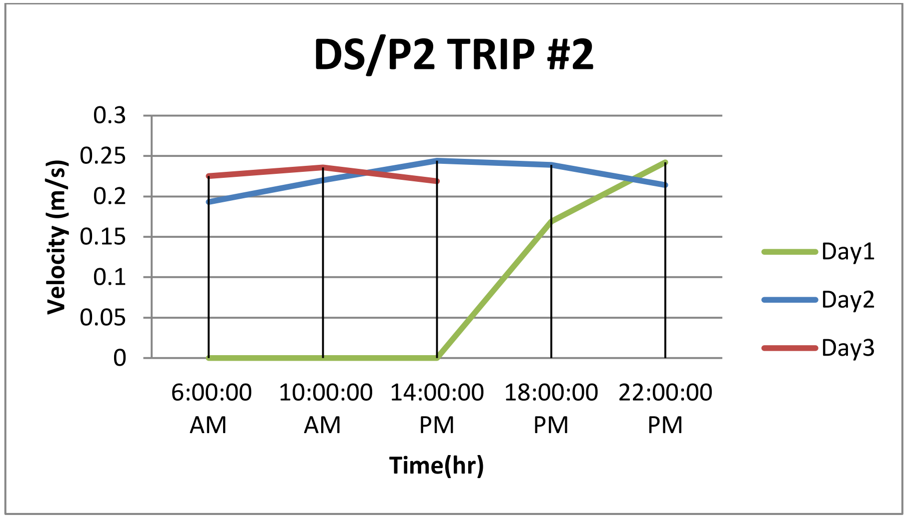


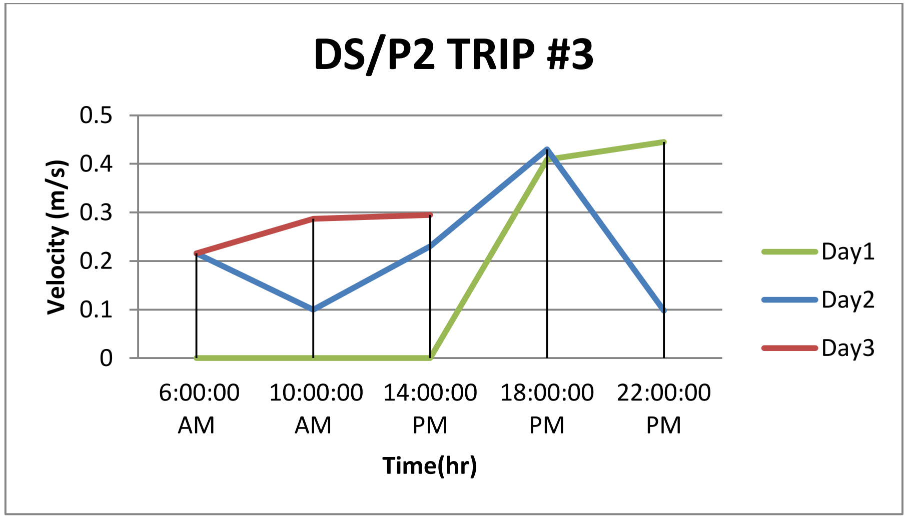


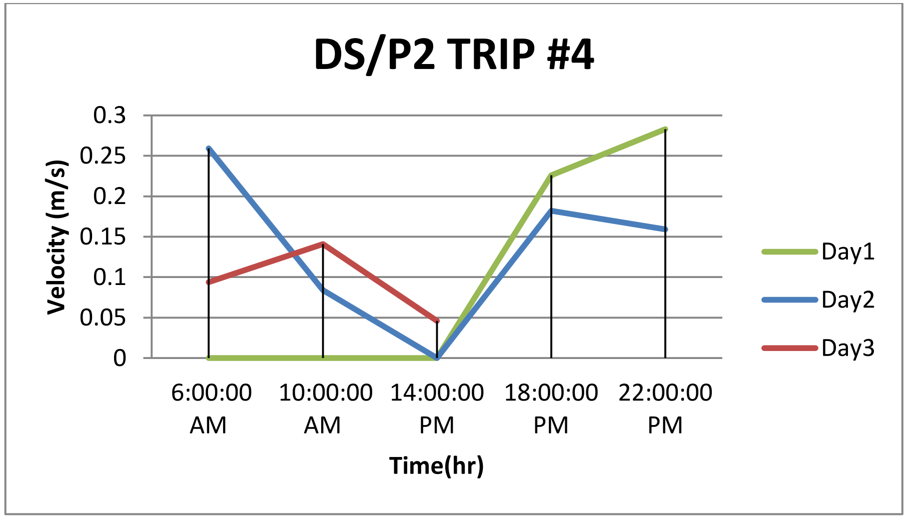


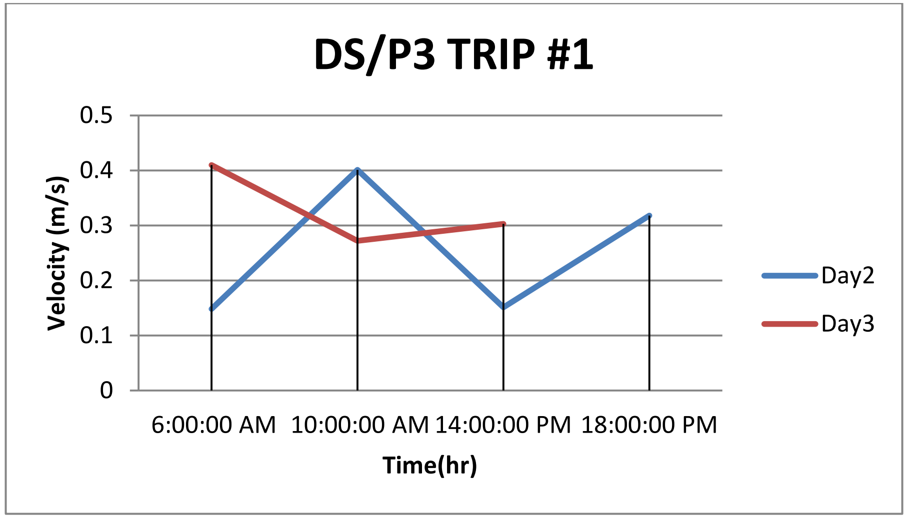


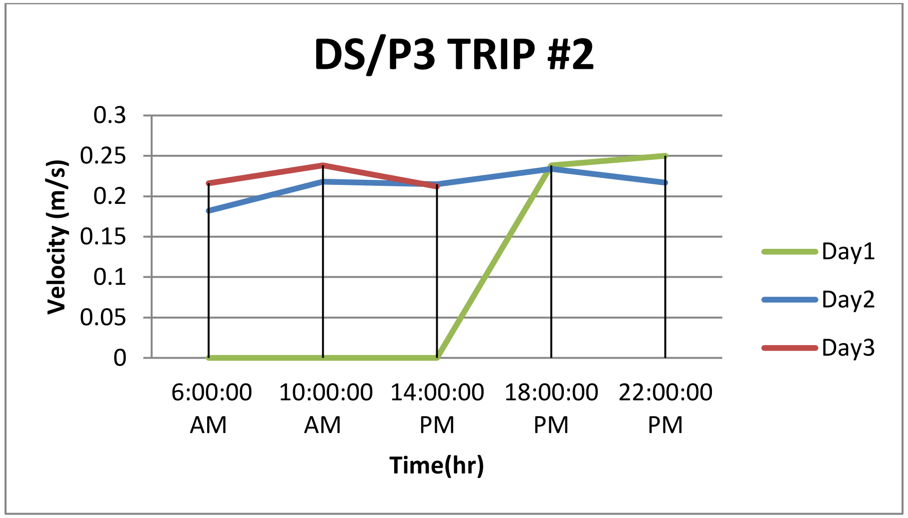

DS/P2 TRIP #1
Velocity (m/s)
0.6
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
Day2
Day3

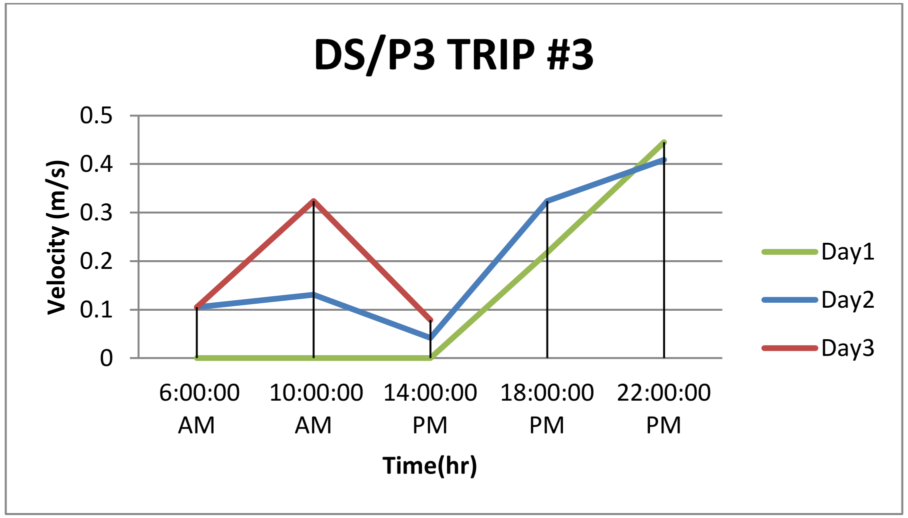

DS/P2 TRIP #2
Velocity (m/s)
0.3
0.25
0.2
0.15
0.1
0.05
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3

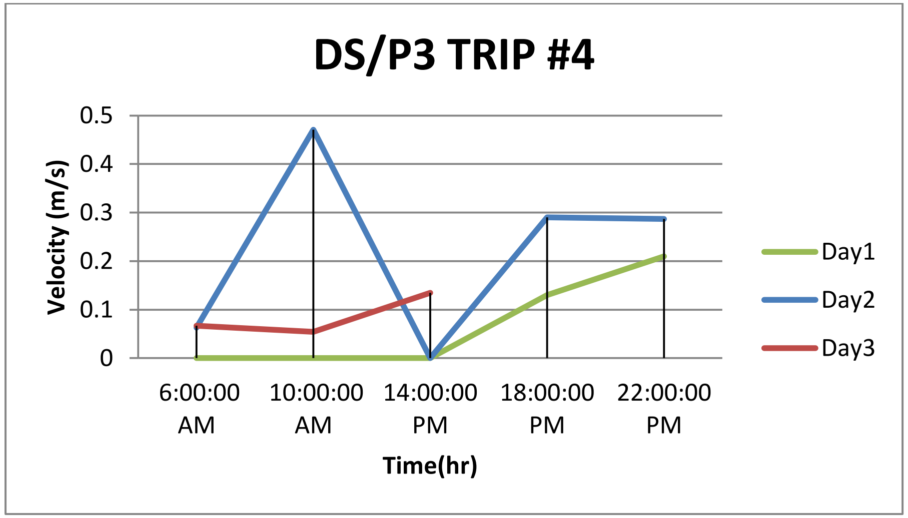

DS/P2 TRIP #3
Velocity (m/s)
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3


DS/P2 TRIP #4
Velocity (m/s)
0.3
0.25
0.2
0.15
0.1
0.05
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3


DS/P3 TRIP #1
Velocity (m/s)
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
Day2
Day3


DS/P3 TRIP #2
Velocity (m/s)
0.3
0.25
0.2
0.15
0.1
0.05
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3


DS/P3 TRIP #3
Velocity (m/s)
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3


DS/P3 TRIP #4
Velocity (m/s)
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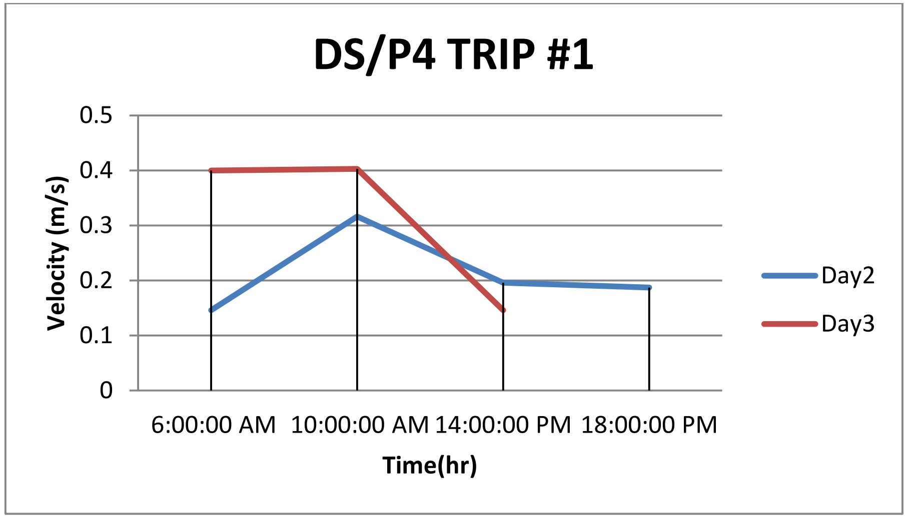
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3


DS/P4 TRIP #1
Velocity (m/s)
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0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
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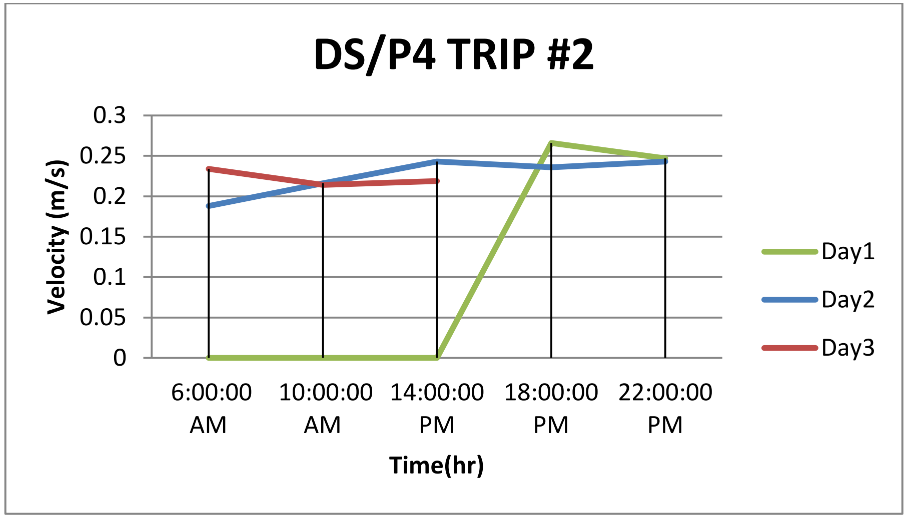
18:00:00 PM
Time(hr)
Day2
Day3


DS/P4 TRIP #2
Velocity (m/s)
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0.2
0.15
0.1
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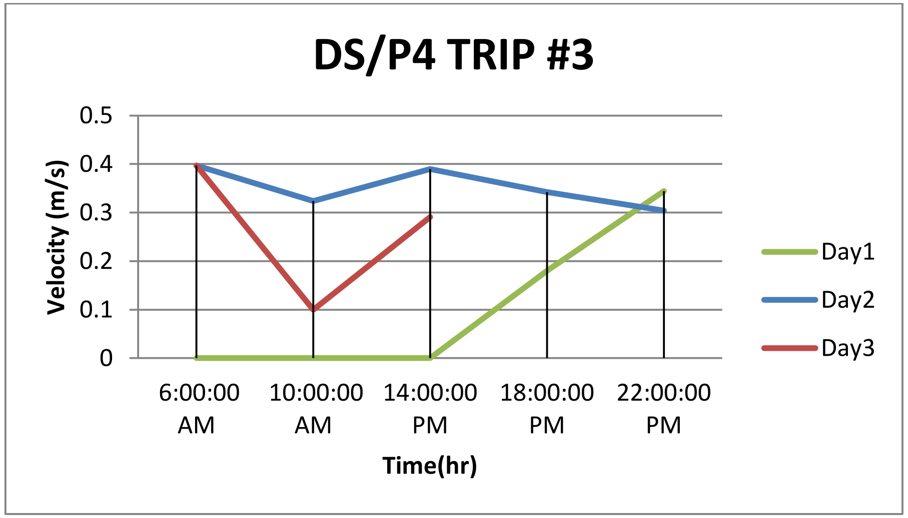
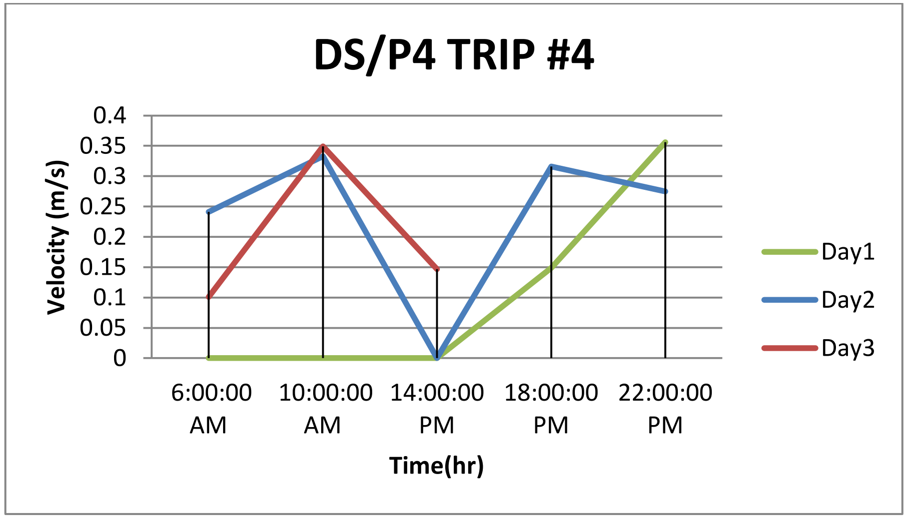
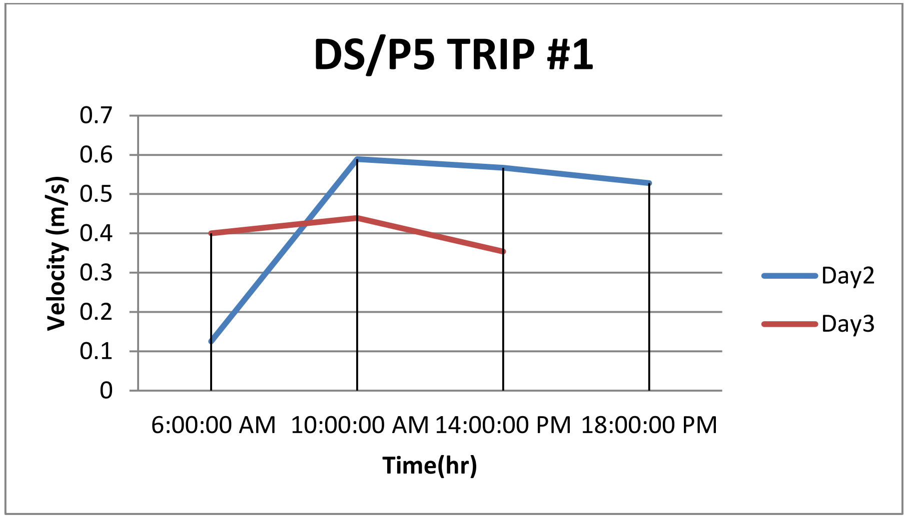
Time(hr)
Day1
Day2
Day3


DS/P4 TRIP #3
Velocity (m/s)
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3


DS/P4 TRIP #4
Velocity (m/s)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3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Velocity (m/s)
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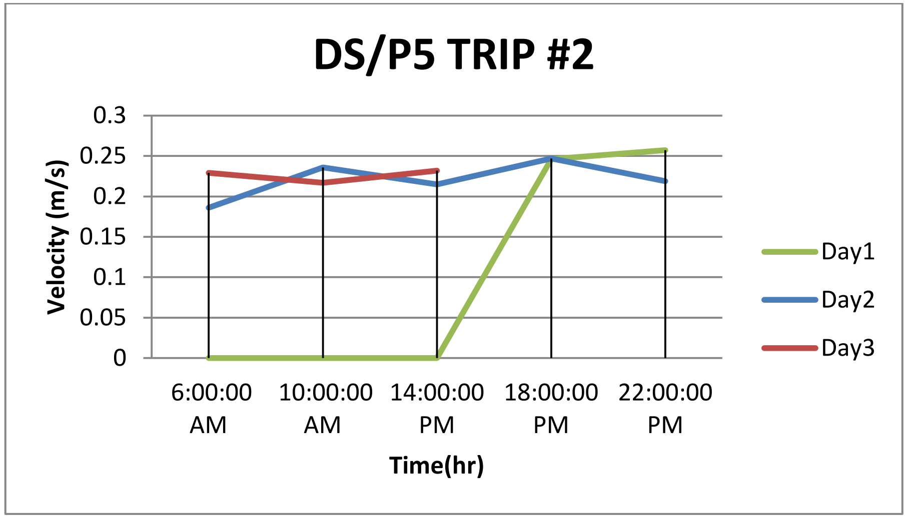
0.6
0.5
0.4
0.3
0.2
0.1
0
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
Time(hr)
Day2
Day3


DS/P5 TRIP #2
Velocity (m/s)
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0.25
0.2
0.15
0.1
0.05
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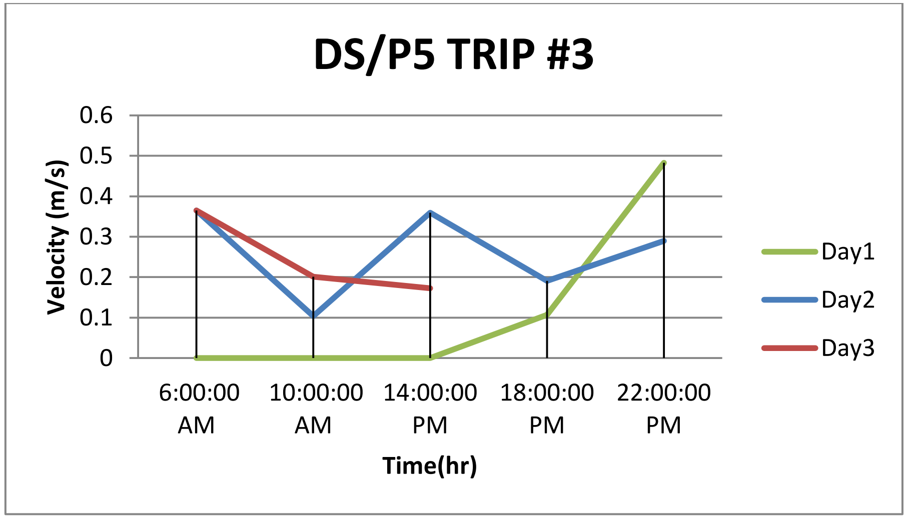
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3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Velocity (m/s)
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0.5
0.4
0.3
0.2
0.1
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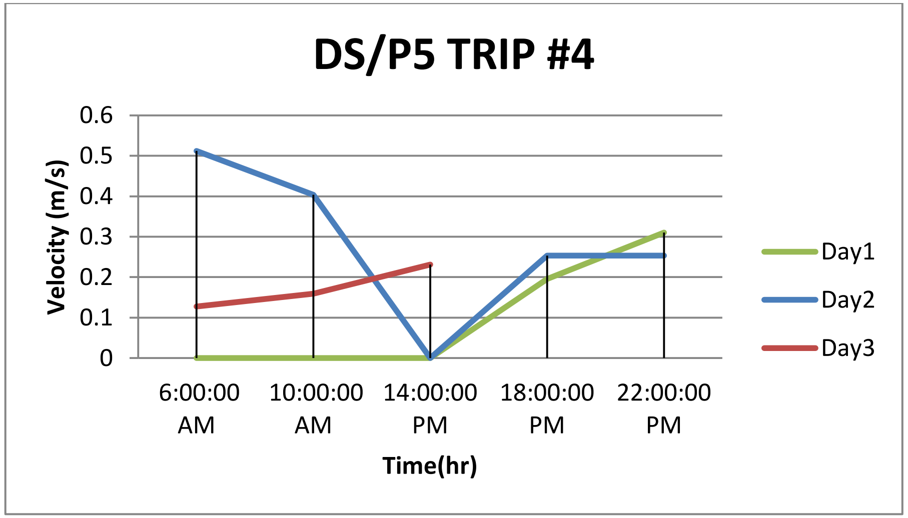
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3


DS/P5 TRIP #4
Velocity (m/s)
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0.5
0.4
0.3
0.2
0.1
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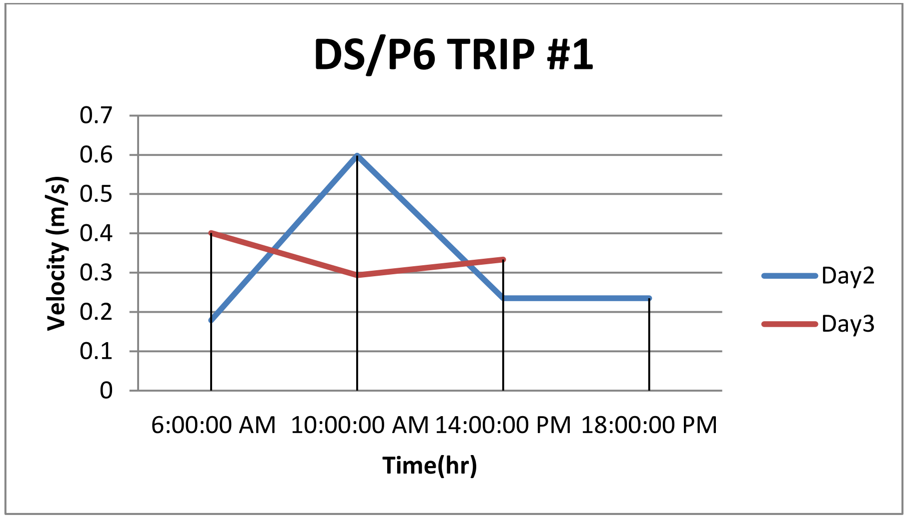
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3


DS/P6 TRIP #1
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Velocity (m/s)
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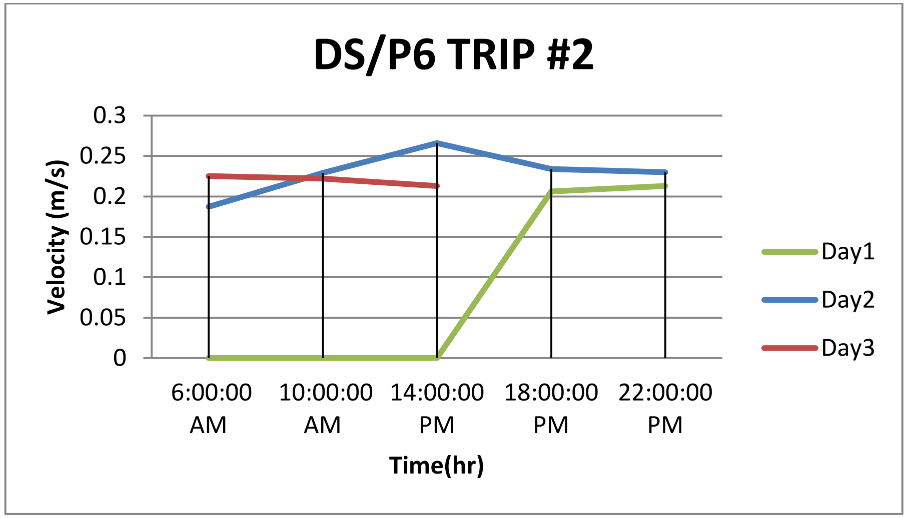
18:00:00 PM
Time(hr)
Day2
Day3


DS/P6 TRIP #2
0.3
0.25
0.2
0.15
0.1
0.05
0
Velocity (m/s)
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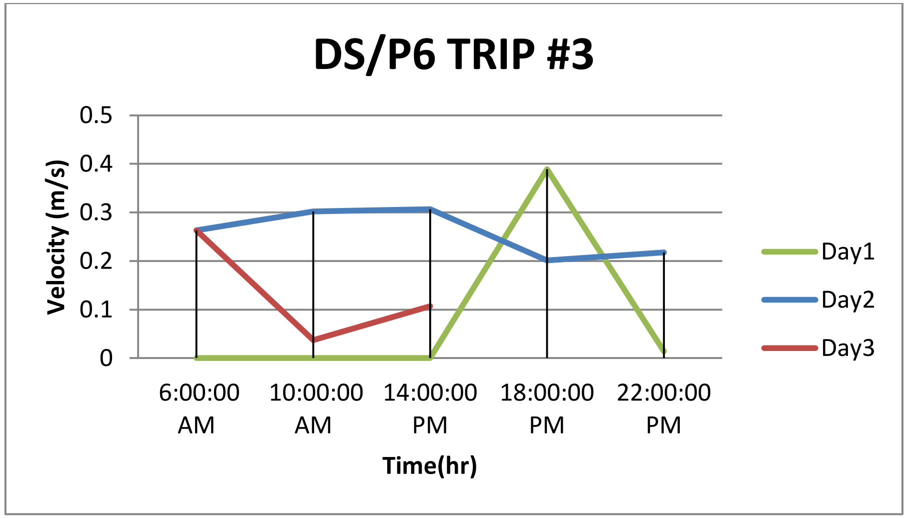
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3


DS/P6 TRIP #3
0.5
0.4
0.3
0.2
0.1
0
Velocity (m/s)
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10:00:00 AM
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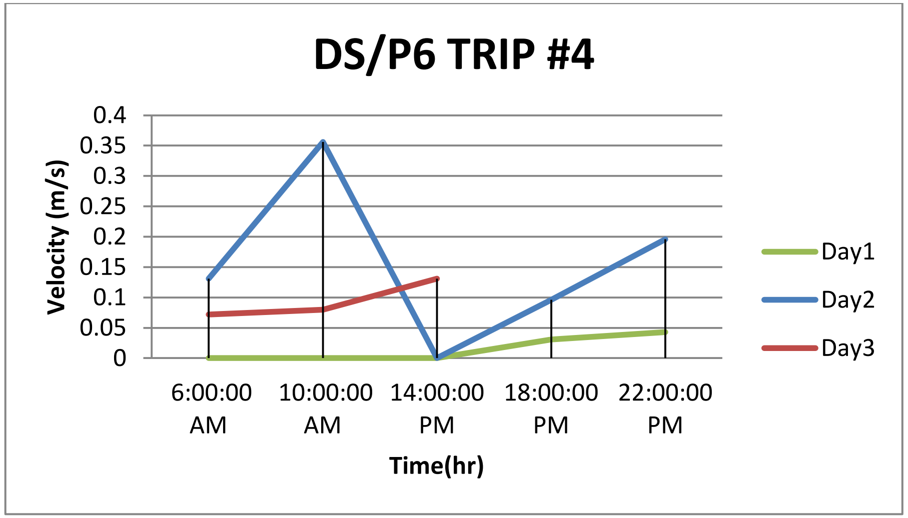
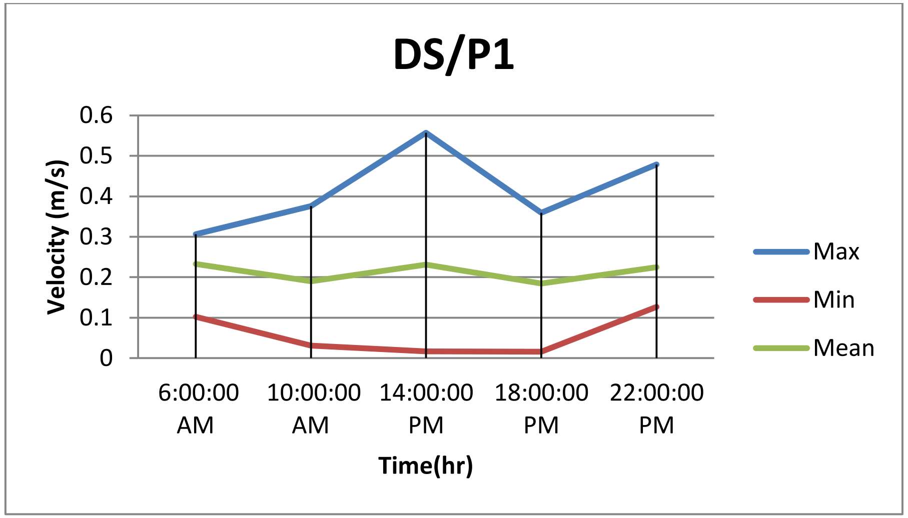
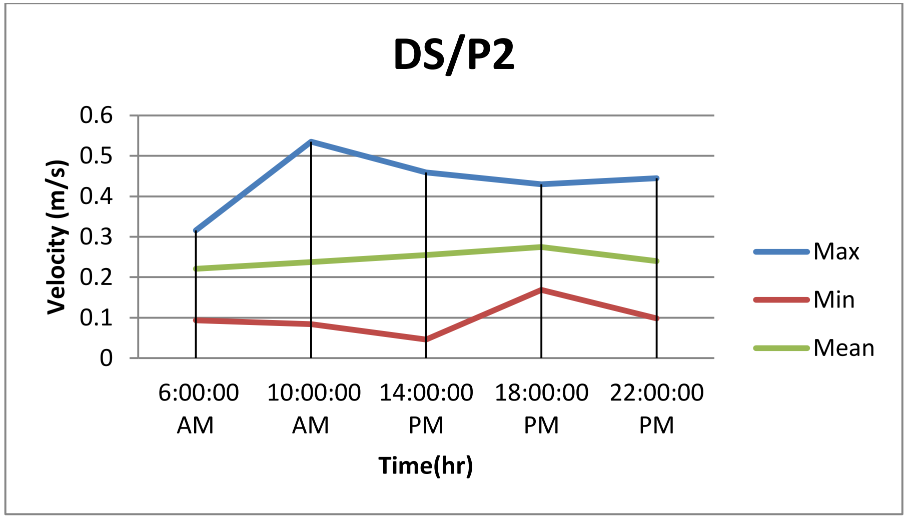
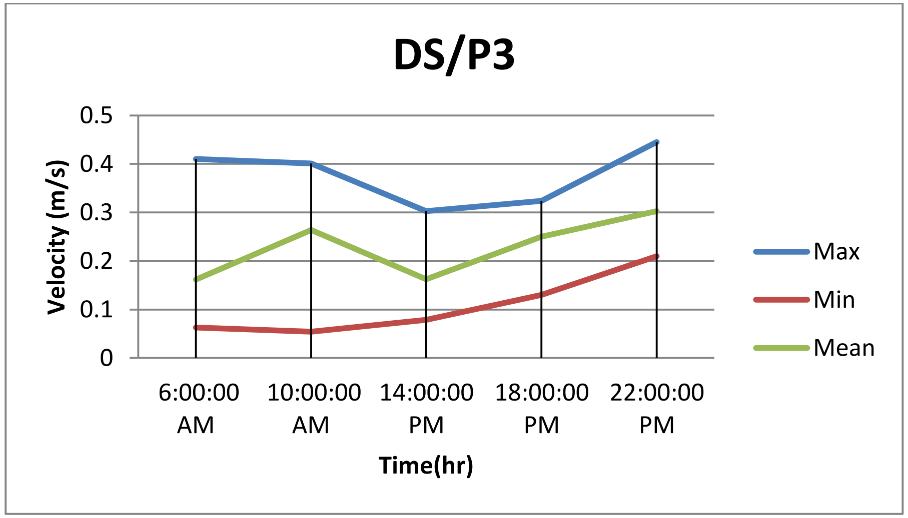
Time(hr)
Day1
Day2
Day3

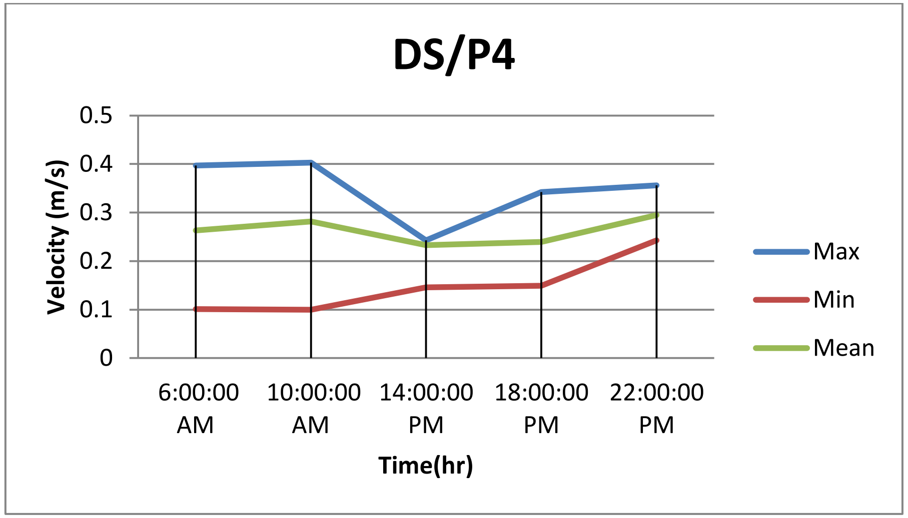

DS/P6 TRIP #4
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Velocity (m/s)
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Day1
Day2
Day3

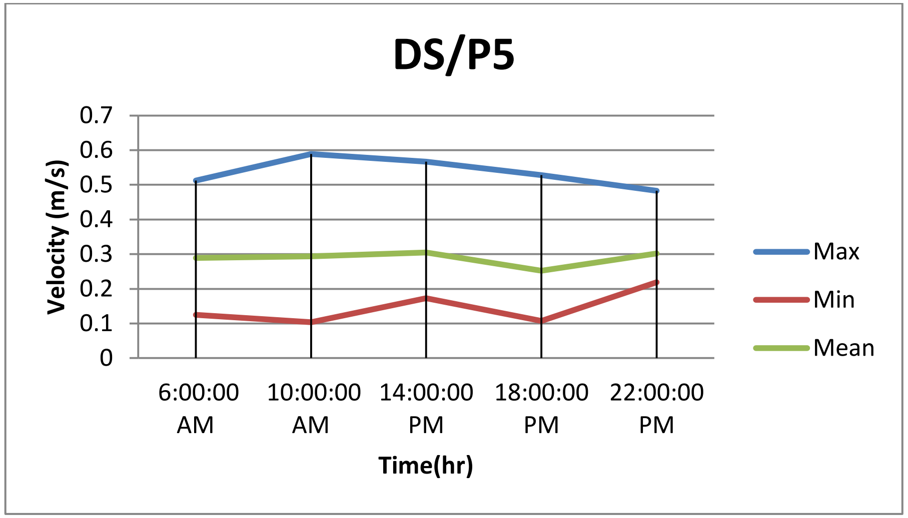
GRAPHS OF MAXIMUM, MINIMUM AND AVERAGE WATER VELOCITY VS TIME (DOWNSTREAM)

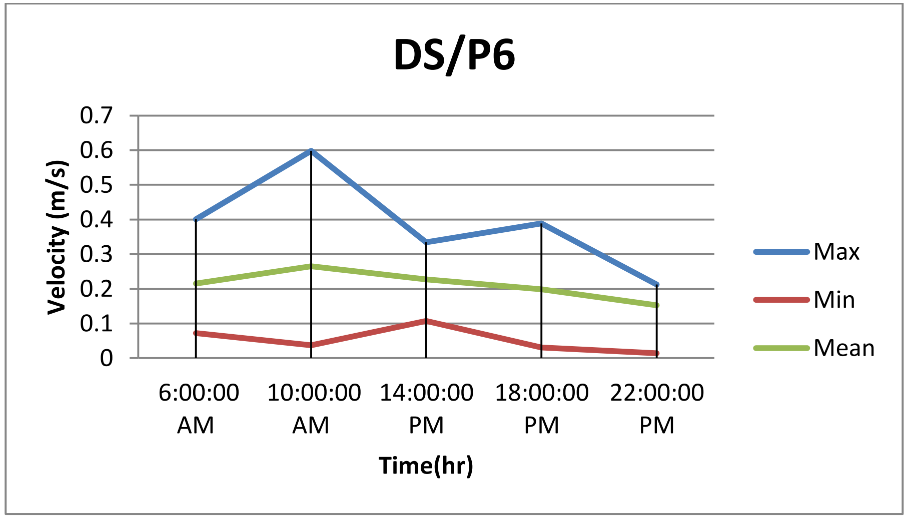







DS/P4
0.5
0.4
0.3
0.2
0.1
0
Velocity (m/s)
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Max
Min
Mean


DS/P5
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Velocity (m/s)
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Max
Min
Mean


DS/P6
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Velocity (m/s)
6:00:00 AM
10:00:00 AM
14:00:00 PM
18:00:00 PM
22:00:00 PM
Time(hr)
Max
Min
Mean